Continuous Crystallization with Gas Entrainment: Evaluating the Effect of a Moving Gas Phase in an MSMPR Crystallizer

Dispersion of a saturated gas in a supersaturated solution has been previously reported to promote nucleation rates during batch crystallization, leading to the exploration of this technique as a cost-effective method to control crystal size distributions. Despite the mechanisms are still unknown, it has been hypothesized that the presence of a flowing gas could promote variations in the flow pattern inside the crystallizer, leading to improved mass transfer and higher rates of secondary nucleation through an increased number of crystal collisions. In this work, we have constructed a lab-scale MSMPR crystallizer with self-induced gas dispersion to investigate the applicability of this technique in continuous crystallization. The effect of different gas hold-ups has been evaluated at high supersaturations and for two different suspension densities. Results show a very limited variation in the overall mass deposition rate, and reductions in the mean FBRM chord length not exceeding 5 μm for the highest investigated gas hold-up (12%). Studying the effect of impeller speed under the same conditions, we found that an increased mixing intensity has a similar impact as gas dispersion, with a mean chord length reduction of 4 μm when the impeller speed was increased from 800 to 950 rpm. These results suggest that the promotion of nucleation kinetics with gas dispersion is limited to systems where crystallization kinetics can be significantly affected by mixing, and demonstrate a limited applicability for crystal size distribution control in continuous MSMPR crystallizers.
Reactivity of sewage sludge, RDF, and straw chars towards NO

The reaction of NO with chars of sewage sludge, refuse derived fuel (RDF), and straw was investigated in a fixed bed reactor at temperatures from 800 to 900°C and NO inlet concentrations from 400 to 1500ppmv. The effect of ash forming elements in the chars was examined by comparing the reactivity of raw and demineralized chars. Compared to straw char, the reaction rates of sewage sludge and RDF char, at 800°C and 400ppmv inlet NO, was an order of magnitude and a factor of six higher, respectively. The very high reactivity of the two waste chars was attributed to the catalytic effect of their large content of calcium and iron. A simple first order globalized rate expression was employed to describe the reactivity of waste chars toward NO, which predicted reasonably well the the conversion of char nitrogen to NO during char combustion at 800°C in 10% O₂. A comparison with literature data revealed a higher reactivity of the waste chars towards NO compared to that of coal and biomass chars. The results in this work provide a simple and validated rate expression to simulate waste char-NO reaction in boilers, and moreover facilitate a potential utilization of waste chars as primary or secondary measures for NO reduction.
Aerodynamic and physical characterization of refuse derived fuel

Physical and aerodynamic characteristics of several refuse derived fuel (RDF) samples were studied. Each RDF sample was tested in a wind sieve to classify the particles into different fractions according to their terminal velocity. The individual particles from the wind sieve were then manually separated according to the material type and physically characterized by weight measurement and 2D photographing. For the tested samples, despite the overall weight distribution of the fractions from the wind sieve was similar, the material distribution of particles in each fraction was significantly different. It has been shown that regardless of the particle material, for each group of particles from the wind sieve test, the ratio of particle maximum projected area to particle mass lies in a narrow range. A new approach based on the particle maximum projected area was proposed to predict the terminal velocity of particles and was tested for each group of particles from the wind sieve experiment. The maximum deviation of the mass-based averaged terminal velocity predicted from the drag model compared to the mid-point wind sieve velocity was smaller than 14%. A procedure was proposed for physical characterization of RDF particles based on the wind sieve test and 2D imaging of particles. This characterization can be used as an input for Computational Fluid Dynamics (CFD) calculations of RDF-fired cement calciners and rotary kilns.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), FLSmidth & Co. A/S
Pages: 7685-7700
Agglomeration mechanism in biomass fluidized bed combustion – Reaction between potassium carbonate and silica sand

Agglomeration is one of the operational problems in fluidized bed combustion of biomass, which is caused by interaction between bed materials (e.g. silica sand) and the biomass ash with a high content of potassium species. However, the contribution of different potassium species to agglomeration is not fully understood yet. In the present work, the reaction between K$_2$CO$_3$ and silica sand has been studied extensively by thermogravimetric analysis. The reacted samples were analyzed by SEM-EDX to reveal the reaction mechanism. The results indicated that the reaction occurs in a solid-solid phase already at temperatures around 700°C. The reaction rate increases with increasing temperature, but decreases with an increase of CO$_2$ partial pressure. Using smaller particle size and well mixed solid reactants results in an increased reaction rate. It is observed that the reaction initiates in the contact area between K$_2$CO$_3$ and silica sand, forming a thin product layer. The layer acted as a reactive media further reacting with K$_2$CO$_3$ and silica sand. The results provide a basis for understanding of potassium induced agglomeration process in fluidized bed biomass combustion.
A heat transfer corrected isothermal model for CFD modeling of biomass devolatilization in fluidized beds

Isothermal models, which neglect particle internal heat transfer, are commonly used in computational fluid dynamic (CFD) modeling of biomass devolatilization in fluidized beds. However, for large biomass particle, the particle internal heat transfer influences significantly the devolatilization, and therefore needs to be considering in CFD modeling. In this work, a heat transfer corrected isothermal model presented in our pervious paper [1] was implemented in Eulerian-Eulerian methods to simulate a batch bubbling fluidized bed for biomass devolatilization. Compared to the conventional isothermal model, the heat transfer corrected isothermal model shown similar computational efficiency of CFD simulations, but for large biomass particles resulted in a lower heating rate and devolatilization rate, which are in better agreement with the observations in particle-scale experiments and simulations. The results demonstrate that the developed heat transfer corrected isothermal model is applicable in CFD modeling of devolatilization of large biomass particles in fluidized beds.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
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Biomass ash induced agglomeration in fluidized bed. Part 2: Effect of potassium salts in different gas composition

Agglomeration is one of the main challenges for combustion and gasification of biomass in fluidized beds. Bed agglomeration is related to K species present in biomass. Understanding the role of different types of K species on formation of agglomerates at different conditions can reveal the mechanisms of biomass ash induced agglomeration. Extensive experiments are conducted in a laboratory scale fluidized bed reactor, using mixtures of quartz sand and K species, including KCl, K₂SO₄ and K₂CO₃, to study the agglomeration mechanisms. The effects of gas composition, including air, H₂– and H₂O– containing gas are investigated. The morphology and elemental analyses of the agglomerate samples are examined by SEM/EDS analysis. Thermodynamic equilibrium calculations are performed for verifying the proposed mechanisms. The results show that the role of various forms of potassium salts on agglomeration in fluidized beds is different. Gas composition also has strong impact on the agglomeration tendency. In the air and H₂-containing gas, defluidization of KCl in a sand bed is caused by the melt of KCl. However, KCl reacts with SiO₂ to form K-silicates in the H₂O-containing gas, which results in a lower defluidization temperature. No defluidization is observed for K₂SO₄ in the presence of oxygen or water. However, K₂SO₄ decomposes and reacts with SiO₂ to form K-silicates, causing defluidization at 850°C in the H₂-containing gas. In the air, H₂– or H₂O-containing gas, K₂CO₃ would react with SiO₂ to form potassium silicates and KOH may be additionally formed in the H₂– and H₂O-containing gas. The possible mechanisms of agglomeration of various potassium salts at different conditions are discussed.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Chinese Academy of Sciences
Contributors: Ma, T., Fan, C., Hao, L., Li, S., Jensen, P. A., Song, W., Lin, W., Dam-Johansen, K.
Pages: 130 - 139
Publication date: 2018
Peer-reviewed: Yes

Publication information
Journal: Fuel Processing Technology
Volume: 180
ISSN (Print): 0378-3820
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.46 SJR 1.453 SNIP 1.729
Web of Science (2017): Impact factor 3.956
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.15 SJR 1.397 SNIP 1.729
Web of Science (2016): Impact factor 3.752
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.09 SJR 1.501 SNIP 1.817
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.96 SJR 1.612 SNIP 2.167
Web of Science (2014): Impact factor 3.352
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.83 SJR 1.61 SNIP 2.121
Characterization of a Multistage Continuous MSMPR Crystallization Process assisted by Image Analysis of Elongated Crystals

This work demonstrates how quantitative image analysis can assist in the characterization of continuous crystallization processes and in the proper selection of mathematical models for the early assessment of crystal quality. An active pharmaceutical ingredient presenting an elongated crystal habit has been crystallized using two stirred tank crystallizers in series. Using image analysis of the crystallization magma, the sources of crystal breakage in the crystallization cascade have been identified and the impact on crystal habit has been evaluated quantitatively. As it is expected for particles presenting high aspect ratios, crystal breakage preferentially occurs in the smallest plane, perpendicular to the largest dimension. This phenomenon is hardly avoidable in downstream production, but it can be accounted with a design approach based on the real crystal dimensions. The kinetic rate equations for nucleation and crystal growth have been determined based on crystal width, from which a model for the accurate prediction of this dimension has been applied. The predicted crystal size distribution is consistent through a moderate degree of crystal breakage during downstream processing.

General information
Diffusion cell investigations into the acidic degradation of organic coatings

Protective organic coatings work by preventing contact between an aggressive environment and a vulnerable substrate. However, the long required lifetime of a barrier coating provides a challenge when attempting to evaluate coating performance. Diffusion cells can be used as a tool to estimate coating barrier properties and lifetime. In this work, a diffusion cell array was designed, constructed, and compared to previous designs, with simplicity being the most important design parameter. Sulfuric acid diffusion through five different coatings was monitored using a battery of cells and a mathematical model was developed to simulate the experimental data and to study diffusion mechanisms. The diffusion cells allowed an objective and fast analysis of coating barrier properties. It was found that sulfuric acid deteriorated these properties as it diffused through the films. This was also expressed in the modeling results, where a three-step time-dependence of the diffusion coefficient was required to simulate both acid breakthrough-time and the subsequent steady state flux. A vinyl ester based coating proved to be the most effective barrier to sulfuric acid diffusion, followed by a polyurethane coating. Amine-cured novolac epoxies provided the least effective protection.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, The Hempel Foundation Coatings Science and Technology Centre (CoaST), CHEC Research Centre, Hempel A/S
Contributors: Møller, V. B., Wang, T., Dam-Johansen, K., Frankær, S. M., Kiil, S.
Number of pages: 15
Pages: 1201-1215
Publication date: 2018
Peer-reviewed: Yes

Publication information
Journal: Journal of Coatings Technology and Research
ISSN (Print): 1547-0091
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.7 SJR 0.415 SNIP 0.894
Web of Science (2017): Impact factor 1.619
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.44 SJR 0.424 SNIP 0.658
Web of Science (2016): Impact factor 1.557
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.45 SJR 0.421 SNIP 0.794
Web of Science (2015): Impact factor 1.342
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.5 SJR 0.512 SNIP 1.045
Experimental and CPFD study of gas–solid flow in a cold pilot calciner

Experimental characterization and computational fluid particle dynamics (CPFD) simulations of a cold pilot-scale cement calciner were carried out to investigate the dispersion and heating of cold cement raw meal particles in the hot gas flow. During the experiments, the gas velocity and temperature were measured at different locations upstream and downstream of the place where the particles were fed to the calciner. The simulations were carried out using Eulerian–Lagrangian approach together with the Multi-Phase Particle-In-Cell (MP-PIC) method, based on the commercially available Barracuda Virtual Reactor® 17.1.0 software. For the particle–free flow, it was shown that the grid–independent velocity profiles predicted from the simulations are in proper agreement with the measured values. For the particle–laden flow, the simulation results from two drag models of EMMS and Gidaspow were compared with the gas temperature measurements and visual observations. The simulation results from the Gidaspow model exhibited an over-prediction of the amount of falling particles to the upstream regions. Both drag models exhibited a local minimum temperature region at a location slightly different from the measured one in a cross-section close to the particle feed position. For the Gidaspow model, a second low gas temperature region was observed at the opposite position of the particle feed that was not detected by the measurements. Overall, it is concluded that the Barracuda Virtual Reactor® software is able to capture the particle dispersion and gas–solid interactions in the studied pilot-scale calciner and the EMMS drag model is more reliable for prediction of the gas–solid flow.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), FLSmidth & Co. A/S, Technical University of Denmark
Pages: 99-115
Publication date: 2018
Peer-reviewed: Yes
Experiments and modeling of single plastic particle conversion in suspension

Conversion of single high density polyethylene (PE) particles has been studied by experiments and modeling. The experiments were carried out in a single particle combustor for five different shapes and masses of particles at temperature conditions of 900 and 1100°C. Each experiment was recorded using a camera. For selected experiments, the center and surface temperatures of the particles were measured using a thermocouple and an IR camera, respectively. During each experiment, the polyethylene particles went through melting, deformation, and decomposition. After the start of decomposition, the surface temperature became almost constant within the range of 480–550°C. The total conversion times of polyethylene particles were mainly influenced by the reactor temperature and particle mass, and the effect of particle shape was less significant. A non–isothermal 1D model was established and validated against the experiments as well as literature data. Furthermore, a simplified isothermal model appropriate for CFD applications was developed, in order to model the combustion of plastic particles in cement calciners. By comparing predictions with the isothermal and the non–isothermal models under typical calciner conditions, it is shown that the accuracy in prediction of the total conversion times of thermoplastic particles is within±30%, for particles lighter than 1000 mg.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), FLSmidth & Co. A/S
Pages: 213-225
Publication date: 2018
Peer-reviewed: Yes

Publication information
Journal: Fuel Processing Technology
Volume: 178
ISSN (Print): 0378-3820
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.46 SJR 1.453 SNIP 1.729
Web of Science (2017): Impact factor 3.956
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.15 SJR 1.397 SNIP 1.729
Web of Science (2016): Impact factor 3.752
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.09 SJR 1.501 SNIP 1.817
Web of Science (2015): Indexed yes
Hydrogen chloride (HCl) absorption by raw meal and raw meal compounds, using in-situ HCl generation and TGA-FTIR tests

HCl emission control optimization from cement plants requires a quantification of the HCl absorption capacity of raw meals (mixtures of fine particles of raw materials) and the determination of raw meal constituent effects on HCl capture below 400 °C. This work reports lab data obtained by ramping temperature tests using a standard TGA-FTIR set-up, a thermally degradable solid HCl source (AlCl₃·6H₂O), industrial raw meals, and mixtures of reagent grade raw meal constituents (SiO₂, CaCO₃, Fe₂O₃, and Al₂O₃). The lab data showed that industrial raw meals had significantly higher HCl absorption capacity than reagent grade CaCO₃. The presence of Fe₂O₃ promoted HCl capture by CaCO₃ between 90 °C and 350 °C. The HCl absorption by raw meals was higher when the HCl source was dispersed rather than when it was placed below the raw meals.
Influence of fuel properties on NOX emission in fluidized bed combustion of biomass

NOX emission from fluidized bed combustion is primarily determined by a series of competing formation and reduction reactions from fuel bound nitrogen. To provide an improved understanding of NOX emission from fluidized bed combustion of biomass, a systematic evaluation of the impact of fuel properties, including nitrogen content, mineral content, and co-combustion, on NOX emission was investigated.

Optimization of Grignard Addition to Esters: Kinetic and Mechanistic Study of Model Phthalide using Flow Chemistry

The kinetics of sequential addition of a distinct Grignard species onto a lactone is studied by flow chemistry. The experimental data are shown to be consistent with a kinetic model based on four reaction steps, reaction of ester to magnesium hemiacetal, rearrangement to ketone (forward and backward) and reaction of ketone to tertiary alcohol upon quenching. The experimental derived reaction mechanism is supported by ab initio molecular computations, and the predicted activation energy is in good agreement with the experimental observations. The Grignard reaction follows a substrate-independent, reductive [2+2] cycloaddition of the Meisenheimer/Casper type. Moreover, the rearrangement equilibrium between magnesium hemiacetal and ketone is characterized and found to be feasible. Monoaddition of the ester carbonyl group is demonstrated for fluorophenyl magnesium bromide, but at reaction conditions at -40 °C with several hours of residence time. Working under cryogenic temperature conditions is essential to realizing monoaddition of the ester carbonyl group with Grignard reagents.
Reaction kinetics for biomass self-ignition at 150–230°C
Replacing coal with pelletized biomass on pulverized-fuel CHP-plants has led to an increased fire risk in storages and processing facilities. Accurate models to predict this behavior are scarce, mainly owing to a lack of reaction kinetic data for low temperatures.

Reactivity of sewage sludge, RDF, and straw chars towards NO
Minimizing NOX emissions from solid fuel combustion is important due to the harmful environmental impact and strict emission regulations. While the gaseous chemistry of nitrogen is fairly well established, the heterogeneous reduction of NO by char is less understood. This study investigated the reduction of NO over sewage sludge, RDF, and straw chars in a fixed bed reactor at varying temperatures and NO inlet concentrations.
Redesign of a Grignard-Based Active Pharmaceutical Ingredient (API) Batch Synthesis to a Flow Process for the Preparation of Melitracen HCl

A Grignard-based batch process, for the preparation of Melitracen HCl, has been redesigned to fit a continuous reactor system. The Grignard addition is carried out at room temperature, with subsequent hydrolysis of the magnesium alkoxide intermediate followed by dehydration of the resulting alcohol. The product undergoes further workup by simple gravimetric phase separation and then crystallization with 2 M HCl in diethyl ether to afford pure Melitracen HCl. All steps in the laboratory setup were concatenated, and the setup was proven capable of producing a significant portion of the commercial quantities of Melitracen HCl. The flow setup profits from a reduced footprint, lower energy consumption, fewer synthetic steps, and reduced raw material usage compared to the batch process.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), H. Lundbeck A/S
Contributors: Pedersen, M. J., Skovby, T., Mealy, M. J., Dam-Johansen, K., Kiil, S.
Pages: 228–235
Publication date: 2018
Peer-reviewed: Yes

Publication information
Journal: Organic Process Research and Development
Volume: 22
Issue number: 2
ISSN (Print): 1083-6160
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.95 SJR 1.405 SNIP 0.978
Web of Science (2017): Impact factor 3.584
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.48 SJR 1.068 SNIP 0.85
Web of Science (2016): Impact factor 2.857
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.54 SJR 1.301 SNIP 1.01
Web of Science (2015): Impact factor 2.922
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.38 SJR 1.033 SNIP 0.982
Web of Science (2014): Impact factor 2.528
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.44 SJR 1.135 SNIP 0.967
Web of Science (2013): Impact factor 2.549
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.32 SJR 1.203 SNIP 1.128
Web of Science (2012): Impact factor 2.739
ISI indexed (2012): ISI indexed yes
Simultaneous acid exposure and erosive particle wear of thermoset coatings

Handling acidic chemicals is a challenge in the chemical industry, requiring a careful choice of contact material. Certain thermoset organic coatings are applicable in low pH environments, but when particulate erosion is also present the performance demand is increased. This is the case in, e.g., stirred tanks for agitated leaching of copper ore, where sulfuric acid is mixed with an erosive slurry. A pilot-scale agitated leaching tank was designed and constructed to explore the performance of selected thermoset coatings in such an environment. For reference, simple immersion experiments were conducted. Coating durability was estimated by observing the film thickness change during exposure. It was found to be a function of film swelling and film contraction, due to chemical exposure, as well as the "polishing" caused by erosive wear. Film reduction rates varied with radial position in the tank bottom-placed coating samples. Maximum rates were found about halfway between the reactor center and wall. Polishing rates also varied significantly with acid concentration, most likely due to chemical reactions taking place between the acid and the coatings, damaging surface mechanical properties, similar to the erosion/corrosion-type phenomena found in metals. A vinyl ester-based coating was the most resistant to the simultaneous erosive/acidic exposure, with a maximum polishing rate of 3.24±0.61 μm/week, while novolac epoxy and polyurethane coatings showed high polishing rates of 11.7±1.50 and 13.4±0.57μm/week, respectively.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, The Hempel Foundation Coatings Science and Technology Centre (CoaST), CHEC Research Centre, Hempel AS
Contributors: Møller, V. B., Dam-Johansen, K., Frankær, S. M., Kiil, S.
Pages: 457–469
Publication date: 2018
**Structure-property relationship in silicone networks**

Silicone networks find use in a broad range of applications in electronic, medical, automobile, aerospace and many other industrial fields. The inherent softness and strong covalent bonds between silicon and oxygen provide the silicone network with most of its favorable properties such as thermal and oxidation stability, flexibility, hydrophobicity, and low surface energy. However, silicone elastomers suffer from poor mechanical properties due to the inherent softness of the network. The mechanical properties of the silicone networks can be improved e.g. by addition of fillers or by chemical modification of the network. Nevertheless, such modifications often come together with deterioration of some of the desirable properties mentioned above.[1]

In this work, different silicone network structures (Fig. 1) and their input on the mechanical properties will be investigated with the main goal to maintain the favorable properties of silicone elastomers while improving the mechanical properties. The different types of silicone network structures will be formed by condensation curing reaction and evaluated with respect to the mechanical properties and long-term stability.

**Sustainable bioenergy and biofuels innovation challenge**

**The Role of Inorganic Matter in Biomass Self-Ignition**

Solid biomass, such as wood pellets, can replace coal for heat and power generation in existing combined heat and power plants. This requires storing and processing such materials in large quantities, where they have shown a tendency to self-heat, and possibly spontaneously ignite. From a plant operator's point of view, it is highly relevant to model and predict such behavior, ideally based on available fuel data. Inorganic matter present in biomass has been known to promote thermal conversion, both under oxidative and inert atmospheres. In this study, biomasses with different inorganic content and composition (pine, beech, wheat straw, sunflower husks) are screened in lab-scale fixed-bed heating experiments, and reaction rates for these materials are determined by thermogravimetric analysis. No clear connection between ash-forming elements naturally present in the biomass materials on one side, and reaction onset behavior or reaction rates at 150–230 °C on the other was found. However, adding KCl to pine wood increased reaction rates compared to the raw sample. The results presented here suggest that catalytic effects play a role, but across different materials, the low-temperature behavior is (likely) dominated by composition in terms of cellulose, hemicellulose, lignin, and extractives. Further research is necessary to confirm these findings.
Acid-resistant organic coatings for the chemical industry: a review

Industries that work with acidic chemicals in their processes need to make choices on how to properly contain the substances and avoid rapid corrosion of equipment. Certain organic coatings and linings can be used in such environments, either to protect vulnerable construction materials, or, in combination with fiber reinforcement, to replace them. However, degradation mechanisms of organic coatings in acid service are not thoroughly understood and relevant quantitative investigations are scarce. This review describes the uses and limitations of acid-resistant coatings in the chemical industry, with a comparison to alternative resistant materials based on metals or ceramics. In addition, coating degradation phenomena, caused by acid exposure, are mapped to the extent possible, and analysis methods for detecting coating degradation type and severity are listed and discussed. It is concluded that more knowledge on chemical and physical degradation mechanisms is required, and that improvements in resistance to elevated temperatures and abrasion would decrease the risk of use and increase the potential application areas of organic coatings exposed to acidic environments in the chemical industry.
Biomass ignition in mills and storages – is it explained by conventional thermal ignition theory?

Self-ignition temperatures determined in the framework of conventional thermal ignition theory does not explain why biomass is much more susceptible to spontaneous ignition in power plant mills or storages. Examining the onset of reactions at low temperatures may provide a better understanding of the process, which can then be incorporated into refined models of self-ignition for biomass and other organic solids. In the present study, the slow, transient heating of several lignocellulosic biomasses and a bituminous coal from ambient temperature to around 300° C were investigated in a lab scale tube oven, with sample sizes between 11–40 g. Tests were carried out under oxidizing (20 % O2) and inert atmospheres. Judged by off-gas measurements of CO and CO₂, a reaction onset could be seen at temperatures below 100° C. Under oxidizing atmosphere, reactions were more intense and set off earlier, suggesting that a heterogeneous oxidation is the dominating mechanism in self-ignition. It could also be shown that both mechanisms compete for reactive material. While oxidation was exothermic, pyrolysis was largely thermally neutral in these experiments. Reaction behavior was seen to depend highly on the material, and the results indicate that higher ash contents may promote reaction onset. However, further work is needed to arrive at a comprehensive model of self-ignition.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), DONG Energy AS
Number of pages: 9
Camera Measurements in Cement Kilns – Impact of Alternative Fuels on Kiln Flames

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, FLSmidth & Co. A/S
Number of pages: 5
Publication date: 2017
Peer-reviewed: Yes
Electronic versions:
Flame_Days_2017_Lars_Schwarzer_CORRECTED.pdf
Research output: Research - peer-review > Paper – Annual report year: 2017

CFD simulations on marine burner flames
The marine industry is changing with new demands concerning high energy efficiency, fuel flexibility and lower emissions of NOx and SOX. A collaboration between the company Alfa Laval and Technical University of Denmark has been established to support the development of the next generation of marine burners. The resulting auxiliary boilers shall be compact and able to operate with different fuel types, while reducing NOx emissions.
The specific boiler object of this study uses a swirl stabilized liquid fuel burner, with a pressure swirl spill-return atomizer (Fig.1). The combustion chamber is enclosed in a water jacket used for water heating and evaporation, and a convective heat exchanger at the furnace outlet super-heats the steam.
The purpose of the present study is to gather detailed knowledge about the influence of fuel spray conditions on marine utility boiler flames. The main goal of work presented in this paper was to obtain a spray description to setup a particle injection region in the CFD simulations of the boiler.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Contributors: Cafaggi, G., Jensen, P. A., Glarborg, P., Clausen, S., Dam-Johansen, K.
Number of pages: 6
Publication date: 2017
Peer-reviewed: Yes
Electronic versions:
Giovanni_Cafaggi_CFD_simulations_on_marine_burner_flames.pdf
Research output: Research - peer-review > Paper – Annual report year: 2017

Development of a Systematic Methodology for Chemical Substitution using a Model-based Approach
Consumer-oriented chemical products, encountered in everyday life, are structured products composed of one or more chemicals and are used by almost everyone. However, although these products are extremely useful in terms of functionality and bring substantial benefits to our lives and health, some of the chemicals constituting these products may be hazardous to the environment and toxic to human health. Besides, in many cases, their chemical production processes generate harmful emissions, which have severe impacts on the environment. The concern about the environment and human health has given rise to the REACH regulation, which compels European chemical companies to stop the use of hazardous substances and replace them with environmentally benign chemicals. Also, the decisions taken during chemical product design have an impact on the process performance as well as product performance. Hence, undoubtedly there is a need to develop a systematic, model-based methodology that can help to find substitutes to existing chemicals in order to improve process economics, operability as well as the sustainability [1], while still delivering the same or improved product functionality. The objective here is to quickly and reliably identify the promising candidates through model-based techniques and then to verify and evaluate them through experiments. In this way, the experimental resources are used for verification rather than trial-and-error search. The goal therefore is to investigate comprehensively the uses and properties of the chemicals of concern; develop a systematic framework to identify, compare and select safer alternatives to these including their corresponding manufacturing processes; and finally design safe chemical products or products with improved product performance. The model-based approach makes use of validated property models [2] to identify the chemicals which need to be substituted, that is, the chemicals that do not meet the desired physico-chemical...
properties and EH&S (environmental, health and safety) properties, and then to generate, evaluate and identify candidates that can replace them. The presentation will highlight the developed methodology and the tools used for chemical substitution along with several case-studies on substitution of chemical compounds in products from cosmetics and personal care; food; pharmaceutical sectors. Several practical examples on substitution of chemicals from chemical-based products in various sectors, like cosmetics and personal care with amino acids (as an additive in a chemical product formulation) along with other well-known substitution problems from sectors like coatings and solvents, automobiles etc., together with the role of property models in chemical substitution, are highlighted.

**General information**

State: Published  
Organisations: KT Consortium, Department of Chemical and Biochemical Engineering, CERE – Center for Energy Ressources Engineering, The Hempel Foundation Coatings Science and Technology Centre (CoaST), CHEC Research Centre  
Contributors: Jhamb, S., Liang, X., Dam-Johansen, K., Kontogeorgis, G., Gani, R.  
Number of pages: 1  
Publication date: 2017  
Peer-reviewed: Yes  
Event: Abstract from 10th World Congress of Chemical Engineering (WCCE10), Barcelona, Spain.

**Diffusion of sulfuric acid in protective organic coatings**

Organic protective coatings and linings are widely used to prevent corrosion in industrial processes. However, the permeation of aggressive chemicals through coatings can induce failures. These are described in the literature, but rarely quantified. To measure the diffusion rates of aggressive chemicals through organic coatings, a diffusion cell was designed. The diffusion cell designed is simple, small and suitable for scaling up to a battery of cells. A concentration profile of H3O+ through epoxy coatings was achieved for sulfuric acid aqueous solutions, which can be used to estimate diffusion coefficients of H3O+. Typically, Crank’s time-lag method is used to estimate the diffusion coefficients but more complicated modelling is required for sulfuric acid solutions. Future modelling work is needed to estimate diffusion behavior of sulfuric acid.

**General information**

State: Published  
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Hempel AS  
Contributors: Wang, T., Møller, V. B., Dam-Johansen, K., Frankær, S. M., Kiil, S.  
Number of pages: 4  
Publication date: 2017  
Peer-reviewed: Yes  

**Effect of Air Injection on Nucleation Rates: An Approach from Induction Time Statistics**

From disruption of the supersaturated solution to improved mass transfer in the crystallizing suspension, the introduction of a moving gas phase in a crystallizer could lead to improved rates of nucleation and crystal growth. In this work, saturated air has been injected to batch crystallizers to study the effects on formation of the first crystal and subsequent turbidity buildup. To account for the typically large sample-to-sample variation, nucleation rates were evaluated for a large number of replicates using probability distributions of induction times. The slope and the intercept of the distributions were studied independently, allowing the simultaneous determination of the mean induction time and a certain detection delay related to the rate of crystal growth after formation of the first nucleus. When saturated air was injected in aqueous glycine solutions, the average detection delay was reduced from 69 to 13 min, and the mean induction time decreased from 128 to 36 min. The effect on aqueous solutions of l-arginine was less apparent, with a detection delay reduction from 15 to 3 min, and no significant changes on the rate of primary nucleation. These results demonstrate the potential of this technique for reduction in nucleation induction time and improved mass deposition rates in crystallization operations.

**General information**

State: Published  
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), H. Lundbeck A/S, Massachusetts Institute of Technology
Electron microscope investigations of activated chalcopyrite particles via the FLSmidth® ROL process

Because of its unique semiconductor properties, the world’s most abundant copper mineral, chalcopyrite (CuFeS2), is refractory with respect to atmospheric leaching using traditional acidic ferric sulfate lixivants. FLSmidth® has developed a novel approach manipulating lattice properties of semi-conducting minerals with the benefit of increasing chemical reactivity and dissolution kinetics. In the FLSmidth® Rapid Oxidative Leach (ROL) process, leach kinetics are still further enhanced by combining chemical and mechanical processes with the assistance of a Stirred Media Reactor. Due to the reduction in surface passivation problems associated with atmospheric leaching, this process is typically able to achieve copper recoveries exceeding 95% in 6 h. An important factor contributing to this extraordinary process performance is a mineral preconditioning step (the focus of this study), which uses between 0.1 and 5 mol percent of copper (II) to dope the lattice and thereby “activate” chalcopyrite. Since lattice restructuring can have such a dramatic influence on semiconductor reactivity, the associated physico-chemical phenomena are worth studying. In this regard, we investigate the relationship between chemical activation and deformation of the chalcopyrite crystal lattice through the use of electron microscopy. Although the activation process took only an hour and the extent of conversion was on the order of a few mol%, the lattice was found to be strained throughout the particle. This paper draws some insights into the impact of applying chemical activation as a pretreatment for mechanochemical processes.

General information

State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), FLSmidth USA Inc.
Contributors: Karcz, A. P., Damø, A. J., Illerup, J. B., Rocks, S., Dam-Johansen, K., Chaiko, D.
Number of pages: 10
Pages: 12044-12053
Publication date: 2017
Peer-reviewed: Yes

Publication information

Journal: Journal of Materials Science
Volume: 52
Issue number: 20
ISSN (Print): 0022-2461
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.83 SJR 0.807 SNIP 1.064
Web of Science (2017): Impact factor 2.993
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.49 SJR 0.769 SNIP 1.072
Web of Science (2016): Impact factor 2.599
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.36 SJR 0.792 SNIP 1.059
Web of Science (2015): Impact factor 2.302
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.54 SJR 0.963 SNIP 1.388
Web of Science (2014): Impact factor 2.371
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.36 SJR 0.926 SNIP 1.451
Web of Science (2013): Impact factor 2.305
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.2 SJR 0.988 SNIP 1.383
Web of Science (2012): Impact factor 2.163
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 2.05 SJR 0.935 SNIP 1.377
Web of Science (2011): Impact factor 2.015
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.957 SNIP 1.091
Web of Science (2010): Impact factor 1.859
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.844 SNIP 0.956
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.68 SNIP 0.773
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.622 SNIP 0.868
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.549 SNIP 0.798
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.561 SNIP 0.879
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.587 SNIP 0.986
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.695 SNIP 1.045
Scopus rating (2002): SJR 0.627 SNIP 0.877
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.734 SNIP 1.015
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.812 SNIP 1.024
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 0.768 SNIP 1.064
Original language: English
Electronic versions:
JMSC_6_27_2017_post_script.pdf. Embargo ended: 28/06/2018
DOI:
10.1007/s10853-017-1308-y
Research output: Research - peer-review › Journal article – Annual report year: 2017
Heat transfer corrected isothermal model for devolatilization of thermally-thick biomass particles

Isothermal model used in current computational fluid dynamic (CFD) model neglect the internal heat transfer during biomass devolatilization. This assumption is not reasonable for thermally-thick particles. To solve this issue, a heat transfer corrected isothermal model is introduced. In this model, two heat transfer corrected coefficients: HT-correction of heat transfer and HR-correction of reaction, are defined to cover the effects of internal heat transfer. A series of single biomass devolatilization case have been modeled to validate this model, the results show that devolatilization behaviors of both thermally-thick and thermally-thin particles are predicted reasonable by using heat transfer corrected model, while, isothermal model overestimate devolatilization rate and heating rate for thermally-thick particle. This model probably has better performance than isothermal model when it is coupled with CFD to model devolatilization of thermally-thick biomass particles.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation
Coatings Science and Technology Centre (CoaST)
Contributors: Luo, H., Wu, H., Lin, W., Dam-Johansen, K.
Number of pages: 12
Publication date: 2017
Peer-reviewed: Yes
Electronic versions:
Heat_transfer_corrected_isothermal_model_for_devolatilization_of_thermally_thick_biomass_particles.pdf
Research output: Research - peer-review ; Paper – Annual report year: 2017

Imaging of Flames in Cement Kilns To Study the Influence of Different Fuel Types

The cement industry aims to use an increased amount of alternative fuels to reduce production costs and CO2 emissions. In this study three cement plants firing different kinds and percentages of alternative fuel were studied. A specially developed camera setup was used to monitor the flames in the three cement kilns and assess the effect of alternative fuels on the flame. It was found that cofiring with solid recovered fuel (SRF) would delay the ignition point by about 2 m and lower the intensity and temperature of the kiln flame compared to a fossil fuel flame. This is related to a larger particle size and moisture content of the alternative fuels, which lowers the conversion rate compared to fossil fuels. The consequences can be a lower kiln temperature and cement quality. The longer conversion time may also lead to the possibility of localized reducing conditions in the cement kiln, which can have a negative impact on the clinker quality and process stability. The burner design may alleviate some of the issues encountered with SRF cofiring. At one of the test plants the burner was changed from a design with an annular channel for axial air to a jet design. This proved to be beneficial for an early ignition and improved dispersion of the fuel and led to an increase in cement quality and higher use of SRF.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation
Coatings Science and Technology Centre (CoaST), FLSmidth & Co. A/S
Pages: 11424-11438
Publication date: 2017
Peer-reviewed: Yes

Publication information
Journal: Energy and Fuels
Volume: 31
Issue number: 10
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
Måling af bundmalingers friktionsmodstand
Bundmalinge anvendes på skibsbunde for at undgå begroning, som øger friktionsmodstanden, og dermed brændstofforbruget, når skibet sejler. Malingerne kan enten være så glatte og elastiske, at begroningen "vaskes af", når skibet sejler eller malingen kan afgive aktive stoffer, der afskærker eller dræber begroningsorganismen. Men hvilken maling giver mindst friktion set over hele skibets levetid?
Mechanisms of agglomeration in fluidized bed: Reactions between potassium carbonate and silica

Agglomeration is one of the main operational problems in fluidized bed combustion of biomass. Agglomeration is induced by interaction between the potassium species present in biomass and the bed materials (i.e. silica sand). To understand agglomeration mechanisms in biomass combustion, mixtures of model potassium compounds (KCl, K₂SO₄, and K₂CO₃) and silica sand were tested in bench scale fluidized bed reactors indicating that only potassium carbonate is able to react with the silica sand particles forming low melting point potassium silicates. The objective of this work is to reveal the reaction mechanism between K₂CO₃ and silica sand, which can be an important step in understanding overall agglomeration mechanism in fluidized bed combustion of biomass. The results indicate that the reaction between K₂CO₃ and silica sand occurred in solid-solid phase with reasonably high reaction rate under fluidized bed combustion temperature (> 800 °C). The initial reaction stage is dominated by surface diffusion of the salt molecules invading fresh silica sand surface, followed by the formation of a thin product layer. The reaction further proceeds by diffusion through the formed product layer. The reaction rate is dependent on temperature, CO₂ partial pressure, particle size and mixing of the reactants. The experimental data obtained in this work provide a basis for further modeling of the agglomeration process in fluidized bed combustion of biomass.

Property Model-Based Chemical Substitution and Chemical Formulation Design

Chemical-based products including structured product formulations and single molecule products have proven to be a boon to mankind and have been a significant part of our economies. Our life and the changes around us cannot be imagined without the presence or involvement of chemicals. But like every coin has two sides, some chemicals constituting these products can also be a curse. This is primarily due to the hazardous environment-related properties that some of these chemicals possess and there are many more chemicals which have not been evaluated due to lack of resources for rigorous, experimental-based estimation methods [1]. Hence, there is a dire necessity to identify such chemicals which may be dangerous to the environment, toxic to human health and harmful for our fragile eco-system. Besides, in many cases, their corresponding chemical production processes generate harmful emissions, which also have
severe impacts on the environment. The concern about the environment and human health has given rise to the REACH regulation implemented by the European Chemical Agency (ECHA), which compels European chemical companies to stop the use of hazardous substances and replace them with environmentally benign chemicals. Additionally, the decisions taken during chemical product design also have an impact on the process and product performance and are influenced by company strategy, availability of market and government policies [2]. Hence, undoubtedly there is a need to develop a systematic, model-based methodology that can help to find substitutes to existing chemicals in order to improve process economics, operability as well as the sustainability, while still delivering the same or improved product functionality. It is useful to start with making structured databases by collecting data from knowledge base, followed by the development of the predictive group-contribution property models and then the development of a general methodology for the model-based chemical substitution and chemical product design. The objective here is to quickly and reliably identify the promising candidates through model-based techniques and then to verify and evaluate their performance and applicability through experiments. In this way, the experimental resources are used for verification rather than for an inefficient, trial-and-error search used for practically all chemical products. Besides, when it is desired to come up with alternative substitutes for the undesirable chemicals, the trial an error based approach will have a very large search space. This could be avoided by having predictive models coupled with the desired target properties, making the identification of these substitutes easier. The goal therefore is to investigate comprehensively the uses and properties of the chemicals of concern; develop a systematic framework to identify, compare and select safer alternatives to these including their corresponding manufacturing processes; and finally design safe chemical product formulations or product formulations with improved product performance. The model-based approach makes use of validated property models to identify the chemicals which need to be substituted, that is, the chemicals that meet the desired physico-chemical properties but not the regulatory (EH&S: environmental, health and safety) properties, and then to generate, evaluate and identify candidates that can replace them. The presentation will discuss the general methodology for chemical substitution, which caters to different problem definitions depending on the reason for substitution. The associated property modeling tools [3] will also be highlighted. A set of new group contribution-based models for a number of useful properties of amino acids will be presented. Through examples on substitution of chemicals from chemical-based products from various sectors namely cosmetics and personal care, pharmaceutical and food, with amino acids (as active ingredient or as additive) will be shown along with other well-known substitution problems. These examples will also highlight the role of property models in chemical substitution and chemical product formulation.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, KT Consortium, CERE – Center for Energy Ressources Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Contributors: Jhamb, S. V., Liang, X., Hukkerikar, A. S., Dam-Johansen, K., Gani, R.
Number of pages: 2
Publication date: 2017
Peer-reviewed: Yes
Event: Abstract from 2017 AIChE Annual Meeting , Minneapolis, United States.
Electronic versions: Property_Model.pdf
Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2017

Understanding Biomass Ignition in Power Plant Mills
Converting existing coal fired power plants to biomass is a readily implemented strategy to increase the share of renewable energy. However, changing from one fuel to another is not straightforward: Experience shows that wood pellets ignite more readily than coal in power plant mills or storages. This is not very well explained by apply-ing conventional thermal ignition theory. An experimental study at lab scale, using pinewood as an example fuel, was conducted to examine self-heating and self-ignition. Supplemental experiments were performed with bituminous coal. Instead of characterizing ignition temperature in terms of sample volume, mass-scaling seems more physically correct for the self-ignition of solids. Findings also suggest that the transition between self-heating and self-ignition is controlled both by the availability of reactive material and temperature. Comparison of experiments at 20% oxygen with those under inert atmosphere revealed two distinct pathways, pyrolysis and exothermic heterogeneous oxidation. At low temperatures and sufficient oxygen availability, heterogeneous oxidation of the solid seems to be favored over pyrolysis for wood, but not for coal. Current ignition models do not reflect the existence of these different pathways, which may be the reason behind the discrepancy between theory and observations.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), DONG Energy AS
Pages: 332 - 337
Publication date: 2017
Host publication information
Acceleration of Anti-Markovnikov Hydroamination in the Synthesis of an Active Pharmaceutical Ingredient

Slow chemical reactions are a big challenge in the modern pharmaceutical industry. Their accelerations together with the introduction of continuous manufacturing modes are major drivers for future development. One example reaction is hydroamination, a reaction between unsaturated hydrocarbons and amines. Such a reaction type is the main focus of this work. More precisely, the anti-Markovnikov hydroamination reaction between cis/trans 9H-thioxanthene-2-chloro-9-(2-propenylidene)-(9CI) and 1-(2-hydroxyethyl)piperazine (HEP) is investigated in detail. It has been traditionally performed in toluene with a huge excess of HEP and reaction times of up to 24h. Acceleration of the reaction from 24 down to 4h is achieved by switching from batch operation mode in toluene to either solvent-free batch mode or microwave-assisted hydroamination with tetrahydrofuran as a solvent.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CAPEC-PROCESS, CHEC Research Centre, H. Lundbeck A/S
Contributors: Mitic, A., Skovby, T., Dam-Johansen, K., Gernaey, K.
Pages: 1821–1827
Publication date: 2016
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering and Technology
Volume: 39
Issue number: 10
ISSN (Print): 0930-7516
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.36 SJR 0.493 SNIP 0.797
Web of Science (2017): Impact factor 1.588
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.47 SJR 0.527 SNIP 0.892
Web of Science (2016): Impact factor 2.051
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.57 SJR 0.606 SNIP 0.907
Web of Science (2015): Impact factor 2.385
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.68 SJR 0.702 SNIP 0.988
Web of Science (2014): Impact factor 2.442
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 1.83 SJR 0.722 SNIP 1.024
Web of Science (2013): Impact factor 2.175
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Agglomeration and Deposition Behaviour of Solid Recovered Fuel

Waste-derived fuels, such as solid recovered fuel (SRF), are increasingly being used in, e.g., the cement industry as a means to reduce cost. The inhomogeneous nature of SRF makes it difficult to combust, and many problems may arise within, e.g., combustion control, feeding of fuel, deposit formation, or accumulation of impurities. The combustion of polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), wood, and SRF were studied in a rotary drum furnace. The combustion was recorded on a camera (60 frames per second), so that any agglomeration or deposition of fuel or ash could be monitored. PE and PP pose no significant risk of forming deposits in a combustion environment (T > 800 °C) as a result of a rapid devolatilization, while PET may cause deposits as a result of a sticky char residue. The deposition tendency of the investigated SRF is low, and it may be managed by a careful combustion control. The ash from SRF or wood does not pose a significant risk of melting and deposits at temperatures up to 1000 °C, but the presence of glass impurities in some SRF may limit operation temperatures to 900 °C as a result of ash melting.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, FLSmith & Co. A/S
Number of pages: 9
Pages: 7858–7866
Publication date: 2016
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 30
Issue number: 10
A Solvent-Free Base Liberation of a Tertiary Aminoalkyl Halide by Flow Chemistry

A flow setup for base liberation of 3-(N,N-dimethylamino)propyl chloride hydrochloride and solvent-free separation of the resulting free base has been developed. Production in flow profits from an on-demand approach, useful for labile aminoalkyl halides. The requirement for obtaining a dry product has been fulfilled by the simple use of a saturated NaOH solution, followed by isolation of the liquid phases by gravimetric separation. The flow setup has an E factor reduction of nearly 50%, and a distillation step has been avoided. The method exemplifies how flow chemistry can be exploited to simplify, improve, and optimize manufacturing processes.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, H. Lundbeck A/S
Contributors: Pedersen, M. J., Skovby, T., Mealy, M. J., Dam-Johansen, K., Kiil, S.
Pages: 2043-2049
Publication date: 2016
Peer-reviewed: Yes

Publication information
Journal: Organic Process Research & Development
Volume: 20
Issue number: 12
ISSN (Print): 1083-6160
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.95 SJR 1.405 SNIP 0.978
Web of Science (2017): Impact factor 3.584
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.48 SJR 1.068 SNIP 0.85
Web of Science (2016): Impact factor 2.857
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.54 SJR 1.301 SNIP 1.01
Web of Science (2015): Impact factor 2.922
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.38 SJR 1.033 SNIP 0.982
Web of Science (2014): Impact factor 2.528
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.44 SJR 1.135 SNIP 0.967
Web of Science (2013): Impact factor 2.549
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.32 SJR 1.203 SNIP 1.128
Web of Science (2012): Impact factor 2.739
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 2.22 SJR 1.213 SNIP 0.909
Engineering model for intumescent coating behavior in a pilot-scale gas-fired furnace

In the event of a fire, intumescent fire protective coatings expand and form a thermally insulating char that protects the underlying substrate from heat and subsequent structural failure. The intumescence includes several rate phenomena, which have been investigated and quantified in the literature for several decades. However, various challenges still exist. The most important one concerns mathematical model validation under realistic exposure conditions and/or time scales. Another is the simplification of advanced models to overcome the often-seen lack of a complete set of input and adjustable model parameters for a given coating, thereby providing models for industrial applications. In this work, these two challenges are addressed. Three experimental series, with an intumescent coating inside a 0.65 m³ gas-fired furnace, heating up according to so-called cellulose fire conditions, were conducted and a very good repeatability was evident. The experiments were run for almost three hours, reaching a final gas temperature of about 1100 °C. Measurements include transient temperature developments inside the expanding char, at the steel substrate, and in the mineral wool insulation placed behind the substrate. A mathematical model, describing the intumescent coating behavior and temperatures in the furnace using a single overall reaction was developed and validated against experimental data. By including a decomposition front movement through the char, a good qualitative agreement was obtained. After further validation against experiments with other coating formulations, it has potential to become a practical engineering tool. This article is protected by copyright. All rights reserved.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Hempel A/S
Contributors: Nørgaard, K. P., Dam-Johansen, K., Català, P., Kiil, S.
Pages: 3947–3962
Publication date: 2016
Peer-reviewed: Yes

Publication information
Journal: AIChE Journal
Entrained flow gasification of coal/bio-oil slurries

Coal/bio-oil slurry (CBS) is a new partial green fuel for bio-oil utilization. CBS reacts with gasification agents at high temperatures and converts into hydrogen and carbon monoxide. This paper provides a feasibility study for the gasification of CBS in an atmospheric entrained flow reactor for syngas production. Experiments have shown that CBS can be successfully processed and gasified in the entrained flow reactor to produce syngas with almost no tar content and low residual carbon formation. High reactor temperature and steam/carbon ratio is favourable for H2 production. At 1400 °C with steam/carbon ratio of 5, the syngas components are similar with that in equilibrium. A synergistic effect exists between coal and bio-oil in coal/bio-oil slurry gasification which might be caused by the catalysis effect of alkali metals and alkaline earth metals in bio-oil.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Chinese Academy of Sciences, Karlsruhe Institute of Technology
Contributors: Feng, P., Lin, W., Jensen, P. A., Song, W., Hao, L., Raffelt, K., Dam-Johansen, K.
Pages: 793-802
Publication date: 2016
Peer-reviewed: Yes

Publication information
Journal: Energy
Volume: 111
ISSN (Print): 0360-5442
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.6 SJR 1.99 SNIP 1.923
Web of Science (2017): Impact factor 4.968
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 5.17 SJR 1.974 SNIP 1.823
Web of Science (2016): Impact factor 4.52
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 5.03 SJR 2.22 SNIP 2.037
Experimental investigation of a draft tube spouted bed for effects of geometric parameters on operation

Experiments are performed in a draft tube spouted bed (DTSB) to investigate effects of the operating conditions and the geometric parameters on the hydrodynamics. Geometry parameters, such as heights of the entrained zone, draft tube
inner diameter, inner angle of the conical section were studied. Increasing the draft tube inner diameter, sharper inner angle of the conical section and higher height of entrained zone increase the internal solid circulation rate and the pressure drop. Even though, for all different configurations, higher gas feeding rate leads to higher internal solid circulation rate considering a maximum value.

**General information**

State: Published  
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre  
Contributors: Azizaddini, S., Lin, W., Dam-Johansen, K.  
Publication date: 2016  
Peer-reviewed: Yes

**Publication information**

Journal: AIP Conference Proceedings  
Volume: 1738  
Article number: 030043  
ISSN (Print): 0094-243X  
Ratings:  
BFI (2019): BFI-level 1  
Web of Science (2019): Indexed yes  
BFI (2018): BFI-level 1  
BFI (2017): BFI-level 1  
Scopus rating (2017): CiteScore 0.26 SJR 0.165 SNIP 0.3  
Web of Science (2017): Indexed yes  
BFI (2016): BFI-level 1  
Scopus rating (2016): CiteScore 0.21 SJR 0.165 SNIP 0.246  
BFI (2015): BFI-level 1  
Scopus rating (2015): CiteScore 0.18 SJR 0.18 SNIP 0.218  
BFI (2014): BFI-level 1  
Scopus rating (2014): CiteScore 0.17 SJR 0.171 SNIP 0.202  
BFI (2013): BFI-level 1  
Scopus rating (2013): CiteScore 0.16 SJR 0.164 SNIP 0.187  
ISI indexed (2013): ISI indexed no  
BFI (2012): BFI-level 1  
Scopus rating (2012): CiteScore 0.14 SJR 0.176 SNIP 0.193  
ISI indexed (2012): ISI indexed no  
BFI (2011): BFI-level 1  
Scopus rating (2011): CiteScore 0.12 SJR 0.161 SNIP 0.16  
ISI indexed (2011): ISI indexed no  
Web of Science (2011): Indexed yes  
BFI (2010): BFI-level 1  
Scopus rating (2010): SJR 0.166 SNIP 0.158  
BFI (2009): BFI-level 1  
Scopus rating (2009): SJR 0.163 SNIP 0.156  
BFI (2008): BFI-level 1  
Scopus rating (2008): SJR 0.17 SNIP 0.132  
Web of Science (2008): Indexed yes  
Scopus rating (2007): SJR 0.171 SNIP 0.176  
Scopus rating (2006): SJR 0.184 SNIP 0.187  
Scopus rating (2005): SJR 0.217 SNIP 0.416  
Scopus rating (2004): SJR 0.198 SNIP 0.249  
Web of Science (2004): Indexed yes  
Scopus rating (2003): SJR 0.153 SNIP 0.063  
Scopus rating (2002): SJR 0.288 SNIP 0.084  
Scopus rating (2001): SJR 0.103 SNIP 0.078  
Web of Science (2001): Indexed yes

Original language: English
Implementation of Near-Infrared Spectroscopy for In-Line Monitoring of a Dehydration Reaction in a Tubular Laminar Reactor

Production of active pharmaceutical ingredients (APIs), fine chemicals, food products, and so on has in recent years been focused on implementing process intensification and process optimization tools. Lower costs and higher selectivity as well as better sustainability and competitiveness are the main benefits. A good approach to achieve this is to perform continuous manufacturing together with satisfying process analytical technology (PAT) requirements. The example studied here is the dehydration reaction of 9-allyl-2-chlorothioxanthen-9-ol ("N714-allylcarbinol") to give a mixture of cis- and trans-9H-thioxanthene, 2-chloro-9-(2-propenylidene)-(9CI) ("N746-butadienes"). A simplified procedure for designing mesoscale tubular reactors is demonstrated together with performance outside of the normal operation windows (higher pressures and temperatures above normal boiling points of solvents). Noninvasive in-line real-time monitoring was established by using Fourier transform near-infrared (FT-NIR) spectroscopy and a suitable partial least squares (PLS) model. High prediction accuracy was achieved and additionally validated by using at-line FT-NIR spectroscopy and off-line HPLC analysis. The presence of impurities was noticed and partly identified in the form of polymers. It is important to note that substrates and products in this work are API intermediates in the production of zuclopenthixol, a product of H. Lundbeck A/S.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CAPEC-PROCESS, CHEC Research Centre, The Danish Polymer Centre, Technical University of Denmark, H. Lundbeck A/S
Contributors: Mitic, A., Cervera Padrell, A. E., Mortensen, A. R., Skovby, T., Dam-Johansen, K., Javakhishvili, I., Hvilsted, S., Gernaey, K.
Number of pages: 8
Pages: 395–402
Publication date: 2016
Peer-reviewed: Yes

Publication information
Journal: Organic Process Research and Development
Volume: 20
Issue number: 2
ISSN (Print): 1083-6160
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.95 SJR 1.405 SNIP 0.978
Web of Science (2017): Impact factor 3.584
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.48 SJR 1.068 SNIP 0.85
Web of Science (2016): Impact factor 2.857
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.54 SJR 1.301 SNIP 1.01
Web of Science (2015): Impact factor 2.922
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.38 SJR 1.033 SNIP 0.982
Web of Science (2014): Impact factor 2.528
Intelligent Heat System – high energy efficient wood stoves with low emissions

This development and demonstration project conducted by HWAM A/S and DTU Chemical Engineering has contributed to the development of an automatically controlled wood stove (HWAM IHS), which is on the market today. The new digital control system ensures optimal combustion conditions by keeping optimal temperatures and overall oxygen concentrations in the combustion chamber throughout a complete wood log combustion cycle.

This improved performance has been verified by field tests in private homes where measurements showed significant reduced emissions and higher efficiency for the IHS stoves compared to traditional manually controlled stoves. The tests also showed that in many cases it is impossible to visually tell if non-optimal combustion occurs. Also, in practice it is impossible to manually control the combustion air as fast and optimally as the automatically controlled air inlet valves.

Emission measurements at the research wood stove set-up at DTU Chemical Engineering showed generally low emissions of particles, well below current standards, and high energy efficiency.

The highest emissions of CO, VOC and PM were seen in the ignition phase while only a small particle peak was observed in the flame phase. The CO emission in the char combustion phase increased due to decreasing temperature in freeboard
– but almost no particle emissions were seen this combustion phase. For the further optimization of the state of art technology of the IHS stoves developed in this project, the improvement of the tertiary air injection showed a considerable potential, which may result in an improved combustion and reduced pollutant emissions. Some important areas of future work include further development of control system sensors and measuring methods, and optimisation of the combustion process and chamber.

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Contributors: Illerup, J. B., Nickelsen, J., Hansen, B. B., Lin, W., Dam-Johansen, K.
Number of pages: 34
Publication date: 2016

**Publication information**
Original language: English
Research output: Research › Report – Annual report year: 2017

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**Surface characterization of activated chalcopyrite particles via the FLSmidth ROL process. Part 1: Electron microscope investigations**
Because of its unique semiconductor properties, the world’s most abundant copper mineral (chalcopyrite) is refractory with respect to atmospheric leaching using traditional ferric sulfate lixivants. A novel approach to address this issue – conducted at FLSmidth – utilizes a mechanochemical Rapid Oxidative Leach (ROL) assisted by a Stirred Media Reactor (SMRt). Due to the elimination of much of the surface passivation problems associated with atmospheric leaching, this process is able to attain copper recoveries >97% in under 6 hours. An optional, rapid preconditioning step uses minute quantities of copper(II) to dope the semiconductor lattice and thereby "activate" the chalcopyrite, thereby reducing leach times below 2 hours (>98% recovery). Because the activation plays a major role in accelerating the leaching step, it is critical to understand the nature of this intermediate and its part in the ROL process. The current work presents results from electron microscope investigations of surface-activated particles.

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), FLSmidth USA Inc.
Contributors: Karcz, A. P., Damø, A. J., Illerup, J. B., Rocks, S., Dam-Johansen, K., Chaiko, D.
Number of pages: 1
Publication date: 2016
Peer-reviewed: Yes
Event: Abstract from Materials Science and Technology 2016, Salt Lake City, UT, United States.
Electronic versions:
Abstract_for_MST_2016_v6.pdf

Research output: Research › peer-review › Conference abstract for conference – Annual report year: 2017

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**Rotor for a pyrolysis centrifuge reactor**
The present invention relates to a rotor for a pyrolysis centrifuge reactor, said rotor comprising a rotor body having a longitudinal centre axis, and at least one pivotally mounted blade being adapted to pivot around a pivot axis under rotation of the rotor body around the longitudinal centre axis. Moreover, the present invention relates to a pyrolysis centrifuge reactor applying such a rotor.

**General information**
State: Published
Organisations: Technical University of Denmark, Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Jensen, P. A., Trinh, N. T., Lundgaard Christensen, R., Dam-Johansen, K., Bech, N.
Publication date: 8 Oct 2015

**Publication information**
IPC: C10B 47/34 A I
Patent number: WO2015150265
Date: 08/10/2015
Priority date: 31/03/2014
Priority number: EP20140162582
Original language: English
Electronic versions:
Advanced combustion control for a wood log stove, Expert workshop - Highly Efficient and Clean Wood Log Stoves

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Contributors: Illerup, J. B., Hansen, B. B., Lin, W., Nickelsen, J., Dam-Johansen, K.
Publication date: 2015
Media of output: PowerPoint

Event information
Event: Expert workshop - Highly Efficient and Clean Wood Log Stoves
Location: Berlin, Germany
Electronic versions:
Berlin_workshop.pdf

Source: PublicationPreSubmission
Source-ID: 140786014
Research output: Research - Sound/Visual production (digital) – Annual report year: 2015

Agglomeration and Deposition Behaviour of Solid Recovered Fuel
Waste derived fuels such as Solid Recovered Fuel (SRF) are increasingly being used in the cement industry as a means to reduce cost [1]. SRF is produced by separating the combustible fraction from industrial or municipal solid waste (MSW). The recovered fraction has a higher content of combustible materials such as plastic and paper than mixed MSW [2]. The inhomogeneous nature of SRF [3] makes it difficult to combust and many problems may arise concerning e.g. combustion control, feeding of fuel [2,4], deposit formation [5], or accumulation of impurities [3]. Laboratory ash fusion tests typically show that SRF ash starts melting in the range of 1150-1200 °C [6–8], which is somewhat lower than most coal ashes.

However, experiments performed in fluidized bed has shown agglomeration taking place as low as 970-990 °C [9,10], and the predictability by ash fusion tests is generally poor [10]. SRF contains significant quantities of common plastics such as polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET). Fluidized bed experiments to examine the pyrolysis of polymers have shown that bed agglomeration can result from melting plastics or sticky char residues in the case of PET [11,12]. The main objective of this study was to characterize the combustion of SRF and especially the deposition propensity of SRF and the main constituents of SRF. This relates both to the low temperature deposits formed during plastic pyrolysis and the high temperature deposits formed by ash. The issues reported in the literature regarding plastic pyrolysis will here be investigated at temperatures above 800 °C that are more common in combustion. It will also be attempted to determine if SRF ash may cause issues below 1000 °C, as indicated by some literature results.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, FLSmidth & Co. A/S, Danish Gas Technology Centre A/S
Number of pages: 6
Publication date: 2015

Host publication information
Title of host publication: Proceedings of The Nordic Flame Days 2015
Electronic versions:
Extended_Abstract_Nordic_Flame_Days_Morten_Nedergaard_Pedersen.pdf
Research output: Research - peer-review › Article in proceedings – Annual report year: 2015

Automatisk styrede brændeovne

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), HWAM A/S
Effects of biofouling development on drag forces of hull coatings for ocean-going ships: a review

This review presents a systematic overview of the literature and describes the experimental methods used to quantify the drag of hull coatings. It also summarizes the findings of hull coating’s drag performance and identifies the main parameters impacting it. The advantages and disadvantages of the reported methods listed in this review provide an assessment of the most efficient methods to quantify the drag performance of hull coatings. This review determines that drag performance of hull coating technology varies depending on whether the coating condition is newly applied, after dynamic or static seawater exposure. The summarized data reveal that, while several methods have attempted to quantify drag performance of hull coatings, other methods must be explored in order to accurately measure the long-term drag performance of hull coatings in conditions mimicking those that ship hulls encounter during actual voyages.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Hempel A/S
Contributors: Lindholdt, A., Dam-Johansen, K., Olsen, S. M., Yebra, D. M., Kiil, S.
Pages: 415-444
Publication date: 2015
Peer-reviewed: Yes

Publication information
Journal: Journal of Coatings Technology and Research
Volume: 12
Issue number: 3
ISSN (Print): 1547-0091
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.7 SJR 0.415 SNIP 0.894
Web of Science (2017): Impact factor 1.619
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.44 SJR 0.424 SNIP 0.658
Web of Science (2016): Impact factor 1.557
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.45 SJR 0.421 SNIP 0.794
Web of Science (2015): Impact factor 1.342
Driven by the growth of the wind power industry during the last decade, the size of wind turbines has grown considerably and single-turbine power can nowadays reach a capacity of 8 MW with rotor diameters exceeding 160 m. Rain erosion is a considerable threat to the mechanical integrity of the blades in such equipment. To reduce expensive blade maintenance repairs and to avoid out-of-service periods, energy-absorbing blade coatings are required to protect rotor blades from rain erosion. In this work we describe the design, construction and evaluation of a laboratory setup for fast screening of up to 22 coating samples that is based on water jet slugs. Our objective is to study the effect of the parameters involved in the rain erosion process and to correlate our experimental results with data obtained with the complex and expensive whirling arm rig, which has become the industry standard method of test for rain erosion. Our results showed that water slug velocity and impact frequency are the most influential parameters in the coating erosion rate. Coating defects, often present on the specimens tested, appeared to play an important role in the erosion mechanism. Two particular experimental blade coatings were investigated using the proposed experimental design. The evaluation of the coatings under conditions where impact frequency and water hammer pressure were "matched" could not be directly correlated with the results obtained with the whirling arm rig. This result may be attributed, among other contributing factors, to the different contact modes in the two setups, i.e. the movement of coated panels against rain drops versus the movement of water drops against coated specimens. Additional factors that require further investigation are the specimen geometries and the potential significance of the presence of a thin water film on the coated surfaces. Our results endorse the complex nature of the rain erosion phenomenon, which is the result of the simultaneous combination of complex mechanisms and as such, it is difficult to reproduce at the laboratory scale.
Estimation of long-term drag performance of fouling control coatings using an ocean-placed raft with multiple dynamic rotors

An experimental setup was designed and built to estimate changes in the skin friction of fouling control coatings (FCC) over an extended period of time in conditions simulating the vast majority of ship profiles (regarding speed and activity) in the present market. The setup consisted of two separate parts: one aged FCCs directly in seawater in a dynamic manner by simulating the exposure condition of a ship’s hull, and a second, laboratory part measured the torque (drag) of aged coatings in a rotary setup. From the spring to the autumn of 2013 and 2014, four commercial FCCs were exposed for 53 weeks in Roskilde Fjord, Denmark, which is characterized by relatively cold seawater and a salinity of approximately 1.2 wt%. The in situ immersion seawater conditions consisted of five-week cycles divided into 2 weeks of static immersion and 3 weeks of dynamic immersion, during which time the cylinders were rotated at a tangential velocity of 8.1 knots. The skin friction was found to generally increase more during the static period, compared to the dynamic ones. Over the course of the entire exposure period, the skin friction of the investigated FCCs decreased in the following order: fluorinated fouling release coating (FRC) (highest skin friction), hydrogel-based FRC without biocides, silylated acrylate self-polishing copolymer coating, and hydrogel-based FRC with biocides (lowest skin friction). However, the differences in skin friction between the latter three coatings were minor and often within the range of experimental uncertainty. The average surface roughness of the FCCs in the newly applied and mechanically cleaned condition, determined as the Rt(50) and R z parameters, was evaluated as poor predictors of skin friction.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Hempel A/S
Contributors: Lindholdt, A., Dam-Johansen, K., Yebra, D. M., Olsen, S. M., Kiil, S.
Pages: 975-995
Publication date: 2015
Peer-reviewed: Yes

Publication information
Journal: Journal of Coatings Technology and Research
Volume: 12
Issue number: 6
ISSN (Print): 1547-0091
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.7 SJR 0.415 SNIP 0.894
Experimental investigation of coating degradation during simultaneous acid and erosive particle exposure

When used in industrial processes, such as stirred acid leaching in the mineral industry, thermoset coatings are exposed to a combination of aggressive chemicals and erosive particle wear. While each exposure condition has been studied separately, no research has been presented on the effects of a simultaneous exposure. To investigate this, a pilot-scale stirred acid leaching tank, containing erosive particles and acidic solutions, has been designed and constructed. Resin types considered are amine-cured novolac epoxy and vinyl ester. Transient coating degradation is mapped through visual inspection and changes in film thickness. The new set-up, capable of experimenting with erosive particles in acidic solutions, is presented. In addition, results from preliminary experiments, using abrasive particles and water in a high-speed disperser, are discussed.

General information

State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Hempel A/S
Contributors: Møller, V. B., Dam-Johansen, K., Frankær, S. M., Kiil, S.
Fuel efficiency and fouling control coatings in maritime transport

First, this thesis concerns the drag performance of fouling control coatings (FCCs) used to protect hulls on ships against biofouling and, therefore, minimize any drag therefrom. A systematic overview of the literature and description of the experimental methods used to quantify the drag of FCCs has been made. Also, the advantages and disadvantages of the reported methods are listed; these provide an assessment of the most efficient methods to quantify the drag performance of FCCs. In addition, the main parameters impacting FCCs and the main findings for the drag performance of the mostly used FCC technologies are outlined. It was found that the drag performance of FCCs varies, depending on whether the FCC has been newly applied, has experienced dynamic exposure, or has experienced static seawater exposure. The summarized data revealed that the most common drag performance method currently used consists of measuring drag when coatings are newly applied and after static immersion. It was found that the main limitation of this method primarily arises due to incorrect exposure conditions, when compared to larger commercial ships that mainly are moving with few and shorter idle periods. As a result, it was determined that other methods must be explored in order to accurately measure the long-term drag performance of FCCs in conditions that mimic those encountered by ships’ hulls during actual voyages.

In an experimental study, five commercial FCC systems were applied to smooth disks with a radius of 11.45 cm. The drag performances in the newly applied coating condition and after one month of static immersion in natural seawater were measured using a friction disk machine (FDM). The four best performing coatings were re-examined for their drag performance after an additional 2.5 months of immersion. The five FCCs in the newly applied coating condition when applied on completely smooth substrates revealed a small difference and, in most cases, one that was less than the experimental uncertainty. After one month of static immersion, the hydrogel-based fouling release coating (FRC) with biocides had the lowest drag, while the fluorinated FRC had the highest drag. The hydrogel-based FRC without biocides and the two self-polishing copolymer (SPC) coatings showed intermediate performances. After 3.5 months of static immersion, the two hydrogel-based FRCs showed superior drag performance, compared to the two SPC coatings. Furthermore, the drag performances of two different FCC systems with varying substrate roughness values (i.e., the roughness below the coating system) were measured in the newly applied condition. An increase in the substrate roughness led to increased drag for both FCC systems, but the FRC was impacted less by the higher substrate roughness than the SPC coating.

To overcome the limitations from investigating only the drag of newly applied coatings and coatings after static immersion, an experimental setup was designed and built to estimate the changes in the skin friction of four FCCs over an extended period of time in conditions simulating the vast majority of ship profiles (i.e., speed and activity) in the present market. The setup consisted of two separate parts; one part aged FCCs directly in seawater in a dynamic manner similar to that experienced by a ship’s hull, and a second, laboratory part measured the torque (drag) of coated cylinders in a rotary setup. Four commercial FCCs were exposed for 53 weeks in Roskilde Fjord, Denmark, i.e., in relatively cold seawater (salinity of 1.2 wt%), from the spring of 2013 to the autumn of 2014. The in situ immersion conditions consisted of five-week cycles. Two weeks consisted of static immersion. This was followed by three weeks of dynamic immersion, in which the cylinders were rotated in natural seawater at a tangential velocity of 8.1 knots. It was found that the skin friction generally increased more during the static immersion, as opposed to the dynamic exposure, which revealed the need for exposure conditions that mimic those of larger commercial ships. Furthermore, with regard to the entire exposure period, it was found that the skin friction of the investigated FCCs decreased in the following order: fluorinated FRC (highest skin friction), hydrogel-based FRC without biocides, silylated acrylate SPC coating, and hydrogel-based FRC with biocides (lowest skin friction). However, the differences in skin friction between the latter three coatings were found to be small and often within the experimental uncertainty. After 25 weeks of immersion and mechanical cleaning, the differences in skin friction were, on average, less than 1%, i.e., within the experimental uncertainty, for velocities relevant for larger commercial ships. The roughness parameters, Rt(50) and Rz, were found to be poor indicators of the drag performance in the newly applied and mechanically cleaned coating condition.
Initial reaction between CaO and SO₂ under carbonating and non-carbonating conditions

The initial kinetics of the CaO/SO₂ reaction have been investigated for reaction times shorter than 1s and in the temperature interval between 450°C and 600°C under both carbonating and non-carbonating conditions (0-20 vol% CO₂) to clarify how recirculating CaO influences the emission of SO₂ from a modern dry kiln preheater system for cement production. Calcined Faxe Bryozo limestone with a particle size smaller than 400μm was utilized as CaO source. It was shown, both theoretically and experimentally, that the observed reaction rates were influenced by mass transport limitations. The results showed that the CaO conversion with respect to SO₂ declined when the CO₂ concentration was increased. Under all conditions, larger specific surface areas of CaO gave higher reaction rates with SO₂. Higher temperatures had a positive effect on the reaction between SO₂ and CaO under non-carbonating conditions, but no or even a negative effect under carbonating conditions. The results led to the conclusion that SO₂ released from raw meal in the upper stages of the preheater does not to any significant extent react with CaO recirculating in the preheater tower.

A collaboration project between the CHEC research Centre, at DTU Chemical Engineering, and the stove manufacturing company HWAM A/S has been established during the last years and has led to development and marketing of wood stoves (Autopilot IHS) equipped with a digital control system. The improved performance has been verified by field tests in private homes. The main components of an Autopilot IHS wood stove are: a modern wood stove with three separate combustion air inlets, and a control system composing of measuring devices for vital process parameters and a system of controlling valves to regulate the individual air flows. The research wood stove set-up at DTU is instrumented with gas analyzers, local temperature measurements, and particle sampling equipment for measurement of particle concentration, size and composition. A detailed study has been conducted to map gaseous and PM emissions for various combustion charges and phases. The experiments showed that the digital control of the combustion process ensures constant and optimal temperatures and overall oxygen concentrations in the combustion chamber resulting in low PM and CO emissions.

General information
Investigation of a Gas-Solid Separation Process for Cement Raw Meal

The gas/solid heat exchanger (2D-HX), developed to replace the cyclone preheaters in cement plants is presented. This design aims at reducing construction height and operation costs. The separation process in the 2D-HX is experimentally investigated, and the results show that separation efficiencies up to 90% can be achieved in the gravitationally driven process. Based on the data, a model of the separation process is developed, utilizing relations from pneumatic transport and cyclone theory. The model fit is acceptable, especially in the area of interest. Based on experimental data, further development of the technology is encouraged.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CAPEC-PROCESS, CHEC Research Centre, FLSmidth & Co. A/S
Contributors: Maarup, C., Hjuler, K., Clement, K., Dam-Johansen, K.
Pages: 921-929
Publication date: 2015
Peer-reviewed: Yes

Publication information
Journal: Procedia Engineering
Volume: 102
ISSN (Print): 1877-7058
Ratings:
Web of Science (2019): Indexed yes
Scopus rating (2017): CiteScore 0.89
Web of Science (2017): Indexed yes
Scopus rating (2016): CiteScore 0.74
Scopus rating (2015): CiteScore 0.56
Scopus rating (2014): CiteScore 0.53
Scopus rating (2013): CiteScore 0.4
ISI indexed (2013): ISI indexed no
Scopus rating (2012): CiteScore 0.28
ISI indexed (2012): ISI indexed no
Scopus rating (2011): CiteScore 0.45
ISI indexed (2011): ISI indexed no
Web of Science (2010): Indexed yes
Original language: English
Keywords: Cement production, Raw meal preheating, Gas/solid heat exchange, Gas/solid separation, Saltation, Modeling
Electronic versions:
Investigation_of_a_Gas_Solid_Separation_Process.pdf
DOIs:
10.1016/j.proeng.2015.01.213

Bibliographical note
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Source: PublicationPreSubmission
Rain erosion of wind turbine blade coatings using discrete water jets: Effects of water cushioning, substrate geometry, impact distance, and coating properties

Rapid and reliable rain erosion screening of blade coatings for wind turbines is a strong need in the coatings industry. One possibility in this direction is the use of discrete water jets, where so-called jet slugs are impacted on a coating surface. Previous investigations have mapped the influence of water jet slug velocity and impact frequency. In the present work, the effects on coating erosion of water cushioning, substrate curvature, and water nozzle-coating distance were explored. The investigations showed that in some cases water cushioning (the presence of a liquid film on the coating surface prior to impact) influences the erosion. Contrary to this, substrate curvature and the water nozzle-coating distance (<100 mm) did not influence the results to any significant degree. Mechanical measurements to characterize selected blade coatings, including tensile strength, flexibility, impact, hardness, and abrasion experiments, were also conducted. The ranking of abrasion resistance of the blade coatings was in agreement with the ranking of rain erosion resistance measured in the whirling arm rig (an industrial standard). Results of this work, with more pertinent parameters explored, confirm the conclusion from the previous investigation that a direct correlation of data from discrete water jet experiments with those obtained in the whirling arm rig does not seem possible (at least not for the blade coatings considered). The underlying mechanisms of rain erosion are substantially different in a setup based on impacting water jet slugs and a setup where a rotor arm impacts falling water drops.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Technical University of Denmark, Hempel A/S
Contributors: Zhang, S., Dam-Johansen, K., Bernad, P. L., Kiil, S.
Number of pages: 9
Pages: 140-148
Publication date: 2015
Peer-reviewed: Yes

Publication information
Journal: Wear
Volume: 328-329
ISSN (Print): 0043-1648
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.31 SJR 1.386 SNIP 2.177
Web of Science (2017): Impact factor 2.96
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3 SJR 1.588 SNIP 2.105
Web of Science (2016): Impact factor 2.531
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.73 SJR 1.512 SNIP 1.997
Web of Science (2015): Impact factor 2.323
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.46 SJR 1.711 SNIP 2.328
Web of Science (2014): Impact factor 1.913
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.37 SJR 1.317 SNIP 2.382
Web of Science (2013): Impact factor 1.862
ISI indexed (2013): ISI indexed yes
Cement production is an energy-intensive process, which traditionally has been dependent on fossil fuels. However, the use of alternative fuels, i.e., selected waste, biomass, and byproducts with recoverable calorific value, is constantly increasing. Combustion of these fuels is more challenging, compared to fossil fuels, because of a lack of experience and different chemical and physical properties. When complete oxidation of fuels in the calciner and main burner is not achieved, they burn in direct contact with the bed material of the rotary kiln, causing local reducing conditions and increasing the internal circulation of S, Cl, Na, and K. Compounds containing these elements, such as alkali salts, evaporate when exposed to high temperatures and subsequently condense in colder parts of the plant. The transformation of the volatile inorganic species at different locations in the cement plant is important, because a high internal circulation affects the process stability and operation through formation of buildups and blockages, ring formation, and shell corrosion, resulting in reduced clinker production, higher heat consumption, and kiln or plant stops. The present review describes the internal cycles of inorganic elements that are established within the cement plant and their dependence on process parameters. Special focus is given to the sulfur cycle. This cycle is intensified by CaSO4 decomposition, making it sensitive to local reducing conditions.
SO₂ Release as a Consequence of Alternative Fuel Combustion in Cement Rotary Kiln Inlets

The combustion of alternative fuels in direct contact with the bed material of the rotary kiln may cause local reducing conditions and, subsequently, decomposition of sulfates from cement raw materials, increasing the SO₂ concentration in the gas phase. The decomposition of sulfates increases the sulfur circulation and may be problematic because high sulfur circulation can cause sticky material buildup, affecting the process operation of the cement kiln system. The SO₂ release from cement raw materials during combustion of pine wood and tire rubber has been studied experimentally in a high-temperature rotary drum, focusing on the influence of the fuel particle size and volatile content. The SO₂ release increased with a decreasing fuel particle size and with an increasing fuel volatile content. Furthermore, CO, H₂, and CH₄, which are the main reducing gases released during fuel devolatilization, were introduced in different concentrations under the bed material. A threshold concentration for each reducing gas, below which no SO₂ release occurs, was found. Introduction of the same molar amount of gas in different concentrations during different time periods showed that a higher reducing gas concentration during a short period (representing fuel devolatilization) released a higher total SO₂ amount compared to a lower concentration during a long period (representing fuel char oxidation).

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, FLSmidth & Co. A/S
Contributors: Cortada Mut, M. D. M., Nørskov, L. K., Glarborg, P., Dam-Johansen, K.
Number of pages: 9
Pages: 2729-2737
Publication date: 2015
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 29
Issue number: 4
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
During operation, the fast-moving blades of wind turbines are exposed to continuous impacts with rain droplets, hail, insects, or solid particles. This can lead to erosion of the blades, whereby the electrical efficiency is compromised and expensive repairs may be required. One possible solution to this problem is elastic blade coatings, which are able to absorb the impact energy without crack formation. The purpose of the work presented in this thesis has been to design and construct a laboratory experimentation device, which allows an accelerated and reliable evaluation of existing or novel blade coating formulations. Results of experiments are compared to data obtained in the larger-size whirling arm rig, which is the present industrial standard for blade coating evaluation. The whirling arm rig consists of three fast-moving horizontal rotors rotating in a heavy artificial rain fall. There are four chapters in the thesis. In chapter 1, a literature survey provides background information to the field. Topics discussed are the global wind energy development, possible wind turbine constructions, blade structures and materials, blade coatings, and liquid erosion mechanisms. In chapter 2, the design,
construction and evaluation of a new laboratory setup for fast screening of 22 coating samples simultaneously is described. The device is based on a principle of discrete water jet slugs. A review of previous rain erosion testing equipment is also included. To provide a basis for comparison of the new setup with the whirling arm rig, a dimensional analysis was conducted and experiments with two polyurethane-based blade coatings carried out. Results showed that water jet slug velocity and impact frequency are the most influential parameters on the coating erosion rate. Furthermore, very small coating surface defects, often present on the specimens tested, appeared to play an important role in the erosion mechanism. The evaluation of the coatings under conditions where impact frequency and water hammer pressure were “matched” could not be directly correlated with the results obtained with the whirling arm rig. This may be attributed, among other contributing factors, to the different contact modes in the two setups, i.e. the movement of coated panels against rain drops versus the movement of water drops against coated specimens. The results endorse the complex nature of the rain erosion phenomenon, which is the consequence of the simultaneous combination of complex mechanisms and as such, it is difficult to reproduce at the laboratory scale. III In chapter 3, the experimental investigation was expanded to a study on the effects of three important process parameters on coating erosion: water cushioning, substrate curvature, and water nozzle-coating distance. In addition, to map the influence of physical properties on rain erosion, mechanical measurements to characterize selected blade coatings, including tensile strength, flexibility, impact, hardness, and abrasion experiments, were conducted. The investigations showed that in some cases water cushioning (the presence of a liquid film on the coating surface prior to impact) is important. Contrary to this, substrate curvature and the water nozzle-coating distance (< 10 cm) did not influence the results to any significant degree. The ranking of abrasion resistance of the blade coatings was in agreement with the ranking of rain erosion resistance measured in the whirling arm rig and is an interesting indication for future work. Finally, in chapter 4, conclusions are drawn and suggestions for further work provided.

**General information**

State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Hempel A/S
Contributors: Zhang, S., Kiil, S., Dam-Johansen, K., Bernad Jr., P. L.
Number of pages: 85
Publication date: 2014

**Publication information**

Place of publication: Kgs. Lyngby
Publisher: Danmarks Tekniske Universitet (DTU)
ISBN (Print): 978-87-93054-49-3
Original language: English
Electronic versions:

Shizhong_Zhang_978_87_93054_49_3_fil_fra_trykkeri.pdf

Research output: Research › Ph.D. thesis – Annual report year: 2015

**Design of Continuous Reactor Systems for API Production**

The pharmaceutical industry has experienced many changes over the last few decades. Continuous production has been promoted as one of the more promising methods for making the industry more efficient and sustainable. The primary focus of this thesis is on the performance of Grignard chemistry in continuous reactor setups. Grignard chemistry encompasses a very powerful reaction type frequently applied in the pharmaceutical industry, for the formation of new carbon-carbon bonds. Three Grignard addition reactions have been studied, all having very different behaviors related to aspects of reaction engineering. A double Grignard addition (two different Grignard reagents) to a lactone was studied with continuous production in mind. The complexity of the reaction was investigated kinetically in order to optimize a potential flow setup. The investigation indicated that reaction temperatures below -40 °C could suppress the formation of an undesired bis-addition product by stabilizing the mono-addition adduct. A Grignard addition to a poorly soluble tricyclic ketone, previously studied in the laboratory, was transferred to full-scale production. Successful upscaling of the laboratory setup to full-scale production equipment enabled complete replacement of the existing batch production of this intermediate. The crowning achievement in this work was the realization of continuous laboratory reactor setups capable of manufacturing the entire GMP portion of the synthesis of melitracen HCl at H. Lundbeck A/S. The formation of a carbon-carbon bond between a tricyclic ketone and a Grignard reagent was the primary objective, this being the first step in GMP synthesis. The process was optimized to include one-step hydrolysis and dehydration, followed by phase separation of the product-containing organic phase, which was then precipitated with hydrogen chloride to obtain the final API. The Grignard reagent was also produced in a continuous laboratory setup involving handling of solid magnesium turnings. Likewise, the alkyl halide used in the formation of the Grignard reagent was produced continuously. The three segmented units were able to be coupled to construct a single continuous reactor facility for manufacturing melitracen HCl. The study of Grignard addition reactions to the three different substrates investigated in this thesis has culminated in a methodology by which reaction engineering decisions can be guided. The methodology provides suggestions on when and how decisions should be made on continuous production methods for Grignard chemistry within pharmaceutical manufacturing. Physicochemical properties, such as solubility, were found to be critical. However, from a business perspective, issues such as the current lifecycle of the API and GMP can make a potential reactor setup non-feasible. If the pharmaceutical industry is to adapt to recent trends towards end-to-end and on-demand pharmaceutical production, access to standard reactor units for commonly-used chemical transformations and methods for timely decision-making are essential. The methodology described herein provides an approach to fulfilling this need for Grignard chemistry in flow
High temperature cement raw meal flowability
The flowability of cement raw meal is investigated at temperatures up to 850°C in a specially designed monoaxial shear tester. Consolidation stresses of 0.94, 1.87 and 2.79kPa are applied. The results show that the flowability is reduced as temperature is increased above 550°C, indicated by increasing unconfined yield strength and reduced flowability factors. Deviation and reproducibility are acceptable for all temperatures except for 850°C where belite formation and possibly calcination sinter the raw meal.
Implementation of a Process Intensification Approach in the Production of an API Intermediate

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CAPEC-PROCESS, CHEC Research Centre, The Danish Polymer Centre, H. Lundbeck A/S, Technical University of Denmark
Contributors: Mitic, A., Cervera Padrell, A. E., Mortensen, A. R., Skovby, T., Dam-Johansen, K., Javakhishvili, I., Gernaey, K.
Publication date: 2014
Peer-reviewed: Yes
Event: Abstract from 2014 AIChE Annual Meeting: American Institute of Chemical Engineers, Atlanta, United States.

Bibliographical note
ORAL PRESENTATION
Source: PublicationPreSubmission
Wood stoves have the potential of providing CO2-neutral energy without transmission loss—but with the significant drawbacks of high emissions of pollutants and particulate matter at low altitude close to private homes, and with an uneven heat release profile which produces non-optimal heating comfort. A collaboration project between the CHEC research centre at DTU Chemical Engineering and the stove manufacturing company HWAM A/S has led to development of an automatic control system for wood stoves, and the first version of an automatically controlled wood stove was launched on the market in 2012. The automatic control system developed for wood stoves in this project ensures optimal combustion conditions, thereby minimizing the emissions throughout a complete wood log combustion cycle. This improved performance has been verified by field tests in private homes.

Investigation of an Intumescent Coating System in Pilot and Laboratory-scale Furnaces
Steel is an incombustible substrate, but at elevated temperatures structural steel suffers from a drastic reduction in mechanical strength. In the event of a fire, the reduced strength may lead to collapse of the structure. A method to prolong the time before steel reaches the critical temperature (450 - 600 °C), at which the collapse may occur, is the use of a fire protective intumescent coating, which swells when exposed to temperatures above about 200 °C. The swelling of the intumescent coating happens according to a complex sequence of chemical reactions, whereby the coating forms a porous char, which thermally insulates the substrate. In addition to the coating itself, several process parameters influence the performance of the intumescent coating. Such parameters may for instance be the interaction with an underlying anticorrosive primer, the heating rate employed, or the oxygen content in the fire. In this work, focus has been on process parameters for an intumescent coating for so-called cellulosic fires.

The thesis contains five chapters, where Chapter 1 is a literature survey providing background knowledge on coatings, intumescent coatings in particular, and fire scenarios. In Chapter 2, the effects of coating thickness and gas-phase oxygen concentration on two epoxy primers used in an intumescent coating system were investigated. It was found that primers with a too high thickness failed in the presence of oxygen. In nitrogen, the primer did well, except for a single case, which showed a minor delamination at the edges. In addition, it was shown that the thermogravimetric behavior of the primer and intumescent coating alone could not be used for explaining the entire coating system performance. A novel experimental method, which may potentially be developed into a fast screening method of primers for intumescent coatings, is also described. Upon heating in nitrogen, a color change of the primer from red to black was observed. Potentially, this may be used as an indicator to whether a primer under an intumescent coating has been exposed to oxygen or not in gas-fired furnace experiments.

In Chapter 3, a mathematical model of an intumescent coating exposed to heating in a pilot-scale gas-fired furnace is presented. The model takes into account convective heat transfer to the char surface, conduction inside the char, and the char expansion rate. Model validation was done against experimental char expansion rates and temperatures of the steel substrate and at intra-char positions. The model was solved in a discretized and non-discretized version and a good qualitative description of the temperature curves was found. An important learning was that temperatures measured inside the char are very important for a proper model validation. Due to its simplicity and few input parameters, the model (non-discretized version) shows a good potential as a practically applicable engineering model. Results suggest that oxygen mass transport is not a limiting factor for the char oxidation reactions. An investigation of the repeatability of the experimental temperatures showed that temperatures close to the char surface were somewhat more uncertain than the steel temperature and char temperatures close to the steel substrate.

Chapters 4 and 5 are concerned with the development of a fast screening method for the extent of expansion and char strength of intumescent coatings. The method is relevant for investigation of special cases, where the char is damaged by moving objects during a fire. The method uses the concept of shock heating to avoid long heating up and cooling down times of a furnace. In Chapter 4, it was found that for measuring char strength reliably at room temperature, dried samples were required. Chapter 5 discusses shock heating in various oxygen concentrations and verified that the expansion is affected by the gas composition. Experimental data showed that under a high heating rate, the char strength could not
meaningfully be correlated to the degree of expansion. Furthermore, it was found that at the high heating rates employed thin films (147 µm) would contract horizontally while expanding vertically. This was not the case with a coating thickness of 598 µm. The strength of the char in the vertical direction was also investigated. It was found that the outer crust of the char had the highest mechanical strength and a weak zone, in the central region of the char, was identified.

**General information**

*State:* Published  
*Organisations:* Department of Chemical and Biochemical Engineering, Hempel A/S  
*Contributors:* Nørgaard, K. P., Dam-Johansen, K., Kiil, S., Català, P.  
*Number of pages:* 140  
*Publication date:* 2014

**Publication information**

*Publisher:* Technical University of Denmark, Department of Chemical and Biochemical Engineering  
*ISBN (Print):* 978-87-93054-64-6  
*Original language:* English  
*Electronic versions:* Kristian_Petersen_Nørgaard_978_87_93054_64_6_fil_fra_trykkeri.pdf  

**Laboratory and gas-fired furnace performance tests of epoxy primers for intumescent coatings**

Protection of steel structures, using so-called intumescent coatings, is an efficient and space saving way to prolong the time before a building, with load bearing steel constructions, collapses in the event of a fire. In addition to the intumescent coating, application of a primer may be required, either to ensure adhesion of the intumescent coating to the steel or to provide corrosion resistance. It is essential to document the performance of the intumescent coating together with the primer to ensure the overall quality of coating system. In the present work, two epoxy primers were used to investigate the potential failure mechanism of a primer applied prior to an intumescent coating. The analysis was carried out using: (1) a gas-fired test furnace, (2) a specially designed electrically heated oven, and (3) thermogravimetric analysis. When tested below an acrylic intumescent coating, exposed to a gas-fired furnace following the ISO834 fire curve (a so-called cellulosic fire), one of the primers selected performed well and the other poorly. From tests in the electrically heated oven, it was found that both primers were sensitive to the film thickness employed and the presence of oxygen. At oxygen-rich conditions, higher primer thicknesses gave weaker performance. In addition, a color change from red to black was observed in nitrogen, while the color remained red in the oxygen-nitrogen mixture. In summary, the results suggest that an adequate choice of primer, primer thickness, and intumescent coating is essential for a good performance of an intumescent coating system. (C) 2014 Elsevier B.V. All rights reserved.

**General information**

*State:* Published  
*Organisations:* Department of Chemical and Biochemical Engineering, CHEC Research Centre, Hempel A/S  
*Contributors:* Nørgaard, K. P., Dam-Johansen, K., Catala, P., Kiil, S.  
*Pages:* 1577-1584  
*Publication date:* 2014  
*Peer-reviewed:* Yes

**Publication information**

*Journal:* Progress in Organic Coatings  
*Volume:* 77  
*Issue number:* 10  
*ISSN (Print):* 0300-9440  
*Ratings:*  
  - BFI (2019): BFI-level 1  
  - Web of Science (2019): Indexed yes  
  - BFI (2018): BFI-level 1  
  - Web of Science (2018): Indexed yes  
  - BFI (2017): BFI-level 1  
  - Scopus rating (2017): SJR 0.844 SNIP 1.288  
  - Web of Science (2017): Impact factor 2.955  
  - Web of Science (2017): Indexed yes  
  - BFI (2016): BFI-level 1  
  - Scopus rating (2016): CiteScore 2.89 SJR 0.852 SNIP 1.335  
  - Web of Science (2016): Impact factor 2.858  
  - BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.84 SJR 0.857 SNIP 1.384
Web of Science (2015): Impact factor 2.632
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.8 SJR 0.997 SNIP 1.585
Web of Science (2014): Impact factor 2.358
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.58 SJR 1.03 SNIP 1.642
Web of Science (2013): Impact factor 2.302
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.39 SJR 1.048 SNIP 1.83
Web of Science (2012): Impact factor 1.848
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 2.34 SJR 0.877 SNIP 1.598
Web of Science (2011): Impact factor 1.977
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.986 SNIP 1.513
Web of Science (2010): Impact factor 1.862
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.826 SNIP 1.332
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.837 SNIP 1.279
Scopus rating (2007): SJR 1.089 SNIP 1.371
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.243 SNIP 1.62
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.939 SNIP 1.15
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.706 SNIP 1.107
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.603 SNIP 1.48
Scopus rating (2002): SJR 1.368 SNIP 1.294
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.625 SNIP 1.031
Scopus rating (2000): SJR 0.784 SNIP 1.137
Scopus rating (1999): SJR 0.714 SNIP 1.128
Original language: English
Keywords: CHEMISTRY,, MATERIALS, FLAME-RETARDANT COATINGS, AMMONIUM POLYPHOSPHATE, INORGANIC FILLERS, MECHANISM, POLYMERS, PROTECTION, RESISTANCE, SYSTEM, BEHAVIOR, Fire safety, Coating compatibility, Intumescent primer, GAS furnaces
DOIs:
10.1016/j.porgcoat.2013.10.018
Source: FindIt
Source-ID: 260934119
Research output: Research - peer-review ; Journal article – Annual report year: 2014
Methane Steam Reforming over an Ni-YSZ Solid Oxide Fuel Cell Anode in Stack Configuration

The kinetics of catalytic steam reforming of methane over an Ni-YSZ anode of a solid oxide fuel cell (SOFC) have been investigated with the cell placed in a stack configuration. In order to decrease the degree of conversion, a single cell stack with reduced area was used. Measurements were performed in the temperature range 600-800 degrees C and the partial pressures of all reactants and products were varied. The obtained rates could be well fitted with a power law expression (r proportional to P-CH4(0.7)). A simple model is presented which is capable of predicting the methane conversion in a stack configuration from intrinsic kinetics of the anode support material. The predictions are compared with the stack measurements presented here, and good agreement is observed.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Department of Energy Conversion and Storage, Mixed Conductors, CHEC Research Centre, Haldor Topsoe AS
Contributors: Mogensen, D., Grunwaldt, J., Hendriksen, P. V., Nielsen, J. U., Dam-Johansen, K.
Number of pages: 8
Publication date: 2014
Peer-reviewed: Yes

Publication Information
Journal: Journal of Chemistry
Volume: 2014
Article number: 710391
ISSN (Print): 2090-9063
Ratings:
Web of Science (2019): Indexed yes
Web of Science (2018): Indexed yes
Scopus rating (2017): CiteScore 0.89 SJR 0.272 SNIP 0.452
Web of Science (2017): Impact factor 1.726
Web of Science (2017): Indexed yes
Scopus rating (2016): CiteScore 0.71 SJR 0.245 SNIP 0.446
Web of Science (2016): Impact factor 1.3
Scopus rating (2015): CiteScore 0.68 SJR 0.238 SNIP 0.457
Web of Science (2015): Impact factor 0.996
Scopus rating (2014): CiteScore 0.55 SJR 0.23 SNIP 0.46
Web of Science (2014): Impact factor 0.772
Web of Science (2014): Indexed yes
Scopus rating (2013): CiteScore 0.8 SJR 0.174 SNIP 0.641
Web of Science (2013): Impact factor
ISI indexed (2013): ISI indexed no
Original language: English
Keywords: CHEMISTRY,, HYBRID SYSTEM, PLANAR SOFC, KINETICS, GAS, PERFORMANCE, CATALYST, MODEL
Electronic versions:
Methane_Steam_Reforming.pdf
DOIs:
10.1155/2014/710391

Bibliographical note
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Source: FindIt
Source-ID: 268575235
Research output: Research - peer-review › Journal article – Annual report year: 2014

Operational Aspects of Continuous Pharmaceutical Production
Introduction of the Process Analytical Technology (PAT) Initiative, the Quality by Design (QbD) approach and the Continuous Improvement (CI) methodology/philosophy is considered as a huge milestone in the modern pharmaceutical industry. The above concepts, when applied to a pharmaceutical production process, should enable better designs of products and processes. Furthermore, easier process monitoring, control and automation are just some of the advantages that can be achieved as a consequence. Traditional production methods of Active Pharmaceutical Ingredients (APIs) are based on batch and semi-batch processes which include plenty of supportive actions defined as non-value
added activities (NVAs) or simply waste. It is therefore desirable to implement a switch from batch based production to continuous manufacturing in order to minimize NVAs, as well as to enable easier satisfaction of the demands defined by the PAT Initiative. This approach could be considered as establishing a Lean Production System (LPS) which is usually supported with tools associated with Process Intensification (PI) and Process Optimization (PO). Development of continuous processes is often connected with many obstacles due to the very long reaction sequences, inhomogeneous reaction mixtures, the presence of slurries, etc. It is therefore important to adapt the reaction conditions as much as possible to the desired production in continuous mode. Small-scale manufacturing could be supported with modern PI tools, such as microwave assisted organic synthesis (MAOS), ultrasounds, meso-scale flow chemistry and microprocess technology. Furthermore, development of chemical catalysts and enzymes enabled further acceleration of some chemical reactions that were known as very slow or impossible to be performed. The main goal of this work is to develop a PI strategy that would include different chemical and physical approaches with the main purpose to accelerate slow chemical reactions and adapt them to continuous manufacturing modes. Detailed insight into the PAT, QbD, CI and Lean Production System (LPS) is additionally provided in the introduction. The practical implementation of the PI strategy is covered with three different examples. The first example process is the dehydration of 9-Alllyl-2-Chlorothioxanthene-9-OI ("N714-Alllycarbinol") to the mixture of cis and trans 9H-thioxanthene,2-chloro-9-2-propenylidene) (Clopenthixol). This chemical reaction is well-known as very slow and difficult to be accelerated by applying chemical catalysts. Therefore, it can be concluded that successful transfer from batch towards meso-flow chemistry is performed together with demonstration of the potential for in-lab and off-line process monitoring. The second example process is the anti-Markovnikov hydroamination between the "N746-Butadienes" and 1-(2-hydroxyethyl)piperazine (H EP) resulting into a mixture of cis/trans 4-[3-(2-Chlorothioxanthene-9-ylidene)propyl]-1-piperazineethanol (Clopenthixol). This chemical reaction is well-known as very slow and difficult to be accelerated by applying chemical catalysts. Therefore, it can be concluded that successful implementation of the PI strategy by using microwave irradiation resulted in significant improvements. The third example process includes the small-scale production of (2-Bromophenyl)(phenyl)sulfane. This important API intermediate is receiving significant attention in the pharmaceutical industry due to the fact that there are plenty of APIs which include C-S bonds in their chemical structure. The production of such compounds is based on Carbon-Sulfur cross coupling reactions, involving expensive chemical catalysts, chemical ligands, bases and unfriendly solvents. Implementation of the PI strategy with a significantly modified chemical pathway resulted in several benefits from an economic, environmental and manufacturing point of view. Considering the results achieved in the case studies, it can be concluded that successful implementation of the PI strategy has been achieved while satisfying the PAT demands and implementing Lean Production System. Significant accelerations of often considered difficult chemical reactions have been achieved, and therefore it can be concluded that a successful transfer from batch towards continuous manufacturing has been achieved.

Performance of a bench-scale fast fluidized bed carbonator

The carbonate looping process is a promising technology for CO2 capture from flue gas. In this process, the CO2 capture efficiency depends on the performance of a carbonator that may be operated as a circulating fluidized bed (CFB). In this paper, the carbonator performance is investigated by applying a new experimental method with accurate control of the particle recirculation rate. The experimental results show that the inlet calcium to carbon molar ratio is the main factor on the CO2 capture efficiency in the carbonator, that is, increasing the inlet Ca/C from 4 to 13 results in increasing the CO2 capture efficiency from 40 to 85% with limestone having a maximum CO2 capture capacity of only 11.5%. Furthermore, a reactor model for a carbonator is developed based on the Kunii-Levenspiel model. A key parameter in the model is the particle distribution along the height of the reactor, which is estimated from experiments under stable operating conditions with constant bed inventory, reactor temperature and exit CO2 concentration. The validated CFB carbonator model was used to simulate different operating conditions relevant for CO2 capture from a power plant and from a cement plant. The results show that particle recirculation rates of 2-5 kg/(m2s) or ratio of bed inventory to recirculation rates of 70-176 s are sufficient for attaining 90% CO2 capture efficiency depending on the inlet Ca to C ratio. © 2014 American Chemical Society.
Properties of slurries made of fast pyrolysis oil and char or beech wood

The properties of slurries made of pyrolysis oil mixed with wood, char or ground char were investigated with respect to phase transitions, rheological properties, elemental compositions, and energy density. Also the pumping properties of the slurries were investigated at temperatures of 25, 40 and 60 C and solid loadings from 0 to 20 wt%. The phase transitions of the wood slurry samples were observed at lower solid loadings compared to the char slurry samples. The apparent viscosity of the slurry samples was found to be considerably impacted by solid loading (0e20 wt%) and temperature (25e60 C), especially in the phase transition region. The slurry viscosities with 20 wt% char loading, 20 wt% ground char loading and 15 wt% wood loading (at a shear rate of 100 s1) are 0.7, 1.0 and 1.7 Pa.s, respectively at 60 C and these values increases 1.2e1.4 times at 40 C and 3e4 times at 25 C. The wood, char and ground char slurry samples with 5e20 wt% solid loading obtain a volumetric energy density of 21e23 GJ/m3. The slurry sample with 20 wt% ground char having a d80 of 118 mm was pumped successfully into a pressurized chamber (0e6 bar) while plugging appeared when the slurry samples with 15 wt% char having a d80 of 276 mm was pumped into the pressurized chamber.

General information

State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Danish Polymer Centre, DONG Energy AS
Pages: 227-235
Publication date: 2014
Peer-reviewed: Yes

Publication information

Journal: Biomass & Bioenergy
Volume: 61
ISSN (Print): 0961-9534
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4 SJR 1.235 SNIP 1.436
Web of Science (2017): Impact factor 3.358
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.71 SJR 1.198 SNIP 1.385
Web of Science (2016): Impact factor 3.219
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.03 SJR 1.51 SNIP 1.596
Release of Chlorine and Sulfur during Biomass Torrefaction and Pyrolysis

The release of chlorine (Cl) and sulfur (S) during biomass torrefaction and pyrolysis has been investigated via experiments in two laboratory-scale reactors: a rotating reactor and a fixed bed reactor. Six biomasses with different chemical compositions covering a wide range of ash content and ash-forming elements were torrefied/pyrolyzed in the temperature range of 150-500 degrees C. The relative release of chlorine and sulfur was calculated based on mass balance and analysis of the biomass before and after torrefaction. In selected cases, measurement of methyl chloride (CH3Cl) in the gas from straw torrefaction has furthermore been conducted. The release of chlorine from straw was first observed at 250 degrees C and peaked with about 60-70% at 350 degrees C. Analysis of the released gas showed that most of the chlorine was released as methyl chloride. Increasing the straw content in the reactor resulted in a lower fractional release of Cl, probably due to more reactive sites in contact with gas phase Cl species leading to secondary binding of Cl to the solid product. Almost complete release of chlorine was observed for woody biomass at 350 degrees C. This result is in agreement with previous studies reporting that biomasses with a lower chlorine content release a higher fraction of chlorine during the pyrolysis process. A significant sulfur release (about 60%) was observed from the six biomasses investigated at 350 degrees C. The initial sulfur content in the biomass did not influence the fraction of sulfur release during torrefaction.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Technical University of Denmark, University Malaysia Pahang, Åbo Akademi University
Pages: 3738-3746
Publication date: 2014
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 28
Issue number: 6
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Impact factor 2.79
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.52
Web of Science (2013): Impact factor 2.733
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
A mathematical model describing the separation of enantiomers by simultaneous preferential crystallization in a coupled crystallizer configuration is developed. The model was validated against experimental data for a chemical model compound, the conglomerate forming system of asparagine monohydrate in water. The kinetic parameters required were taken from available literature sources and simulations compared to experimental data. Simulations were found to be in good agreement with experimental data. Additional model simulations suggest that the separation process can be improved by increasing the mean residence time of the liquid phase in the crystallizers, and the mass of seeds supplied. Reducing the size of seed crystals will also lead to an improved separation. The model can also be used to simulate the performance of the crystallization process for a racemic compound forming system. The racemic compound and the pure enantiomer can be separated simultaneously in each crystallizer, having sufficient enrichment of the pure enantiomer in the feed solution. The model can also be extended to represent a fully continuous separation process taking into account the continuous supply of enantiopure seed crystals and liquid feed solution and the continuous removal of solid product and mother liquor.

**General information**

State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Technical University of Denmark, H. Lundbeck A/S
Contributors: Chaaban, J. H., Dam-Johansen, K., Skovby, T., Kiil, S.
Pages: 601-612
Publication date: 2014
Peer-reviewed: Yes
Sulfur Release during Alternative fuels Combustion in Cement Rotary Kilns

Cement production is an energy-intensive process, which has traditionally been dependent on fossil fuels. However, the usage of selected waste, biomass, and by-products with recoverable calorific value, defined as alternative fuels, is increasing and their combustion is more challenging compared to fossil fuels, due to the lack of experience in handling the different and varying combustion characteristics caused by different chemical and physical properties, e.g. higher moisture content and larger particle sizes. When full combustion of alternative fuels in the calciner and/or main burner is not achieved, partially or unburned solid fuels may drop into the material bed in direct contact with the bed material of the rotary kiln. The combustion of alternative fuels in direct contact with the bed material of the rotary kiln causes local reducing conditions and may alter the input and the behavior of minor elements into the kiln system. The minor elements of concern are sulfur, chlorine, so dium, and potassium, which are known to be circulating or volatile elements in the kiln system. Compounds containing these elements evaporate, when exposed to high temperatures, and may subsequently condense in cooler parts of the plant. High internal circulation seriously affects the process stability and operation of the cement kiln system, such as material build-ups in the cyclones and/or in the rotary kiln as rings, and on a longer time-scale by shell corrosion. This thesis provides a detailed analysis of the circulating ion of the volatile elements and the transformation of different species containing these elements at different locations in the cement plant. This is complemented by thermodynamic calculations for a better understanding of the inorganic chemistry in the rotary kiln. The main focus is given to SO$_2$ release due to decomposition of calcium sulfate in the kiln inlet and the modification of the sulfur circulation during alternative fuel combustion, because sulfur is the most affected element by reducing combustion conditions. Sulfur release from cement raw materials during alternative fuel combustion is experimentally investigated using pine wood and tire rubber particles in a pilot scale set-up, which is able to simulate the process conditions in the material inlet end of an industrial rotary kiln. The SO$_2$ release increases with decreasing fuel particle size, oxygen content in the freeboard gas, and increasing sulfur content in the bed material. Experiments with wood with different degree of volatiles show that the sulfur release mainly takes place during devolatilization. This is supported by the finding of the industrial investigation on sulfur released, where no clear relationship is observed between the carbon from the fuel, mainly expected to be in the form of char, entering in the rotary kiln, and the sulfur recirculation. The effect of different concentrations and binary mixtures of the main reducing agents released from fuels on sulfur release are investigated experimentally in order to separate the influence of the simultaneous phenomena occurring in the experimental set-up, such as mixing the fuel with the bed material, heating up of a particle, iii Abstract Cement production is an energy-intensive process, which has traditionally been dependent on fossil fuels. However, the usage of selected waste, biomass, and by-products with recoverable calorific value, defined as alternative fuels, is increasing and their combustion is more challenging compared to fossil fuels, due to the lack of experience in handling the different and varying combustion characteristics caused by different chemical and physical properties, e.g. higher moisture content and larger particle sizes. When full combustion of alternative fuels in the calciner and/or main burner is not achieved, partially or unburned solid fuels may drop into the material bed in direct contact with the bed material of the rotary kiln. The combustion of alternative fuels in direct contact with the bed material of the rotary kiln causes local reducing conditions and may alter the input and the behavior of minor elements into the kiln system. The minor elements of concern are sulfur, chlorine, so dium, and potassium, which are known to be circulating or volatile elements in the kiln system. Compounds containing these elements evaporate, when exposed to high temperatures, and may subsequently condense in cooler parts of the plant. High internal circulation seriously affects the process stability and operation of the cement kiln system, such as material build-ups in the cyclones and/or in the rotary kiln as rings, and on a longer time-scale by shell corrosion. This thesis provides a detailed analysis of the circulating ion of the volatile elements and the transformation of different species containing these elements at different locations in the cement plant. This is complemented by thermodynamic calculations for a better understanding of the inorganic chemistry in the rotary kiln. The main focus is given to SO$_2$ release due to decomposition of calcium sulfate in the kiln inlet and the modification of the sulfur circulation during alternative fuel combustion, because sulfur is the most affected element by reducing combustion conditions. Sulfur release from cement raw materials during alternative fuel combustion is experimentally investigated using pine wood and tire rubber particles in a pilot scale set-up, which is able to simulate the process conditions in the material inlet end of an industrial rotary kiln. The SO$_2$ release increases with decreasing fuel particle size, oxygen content in the freeboard gas, and increasing sulfur content in the bed material. Experiments with wood with different degree of volatiles show that the sulfur
release mainly takes place during devolatilization. This is supported by the finding of the industrial investigation on sulfur release, where no clear relationship is observed between the carbon from the fuel, mainly expected to be in the form of char, entering in the rotary kiln and the sulfur recirculation. The effect of different concentrations and binary mixtures of the main reducing agents released from fuels on sulfur release are investigated experimentally in order to separate the influence of the simultaneous phenomena occurring in the experimental set-up, such as mixing the fuel with the bed material, heating up of a particle, devolatilization, char combustion, the reactions between CaSO₄ and the different reducing agents, and the oxidation of the volatiles gases in the free board. The main reducing agents are CO, CH₄ and H₂, which are introduced under the bed material in the high temperature rotary drum to characterize the SO₂ release under variation of temperature, oxygen content in the gas, and time of exposure. A threshold concentration for each reducing gas, below which no SO₂ release occurs, is found. The reducing concentration and the time of exposure are of high importance for SO₂ release because it is shown that introducing the same total amount of gas, the highest reducing agent concentration for a short period released a higher total SO₂ amount compared to the lowest concentration during a long period. A mathematical reaction based model for predicting sulfur release caused by volatiles from wood particles fired in the material kiln inlet is developed and evaluated against pilot scale data, which shows that the model follows the experimental data tendency. The model can predict SO₂ release varying particle size, fill degree, and firing degree but the effect of sulfur content in the bed cannot be predicted. Further development regarding particle motion according to the rotational speed may be needed. Furthermore, a model for predicting the tendency of build-ups for a kiln system is developed based on the prediction of SO₃ and Cl concentrations in the hot meal. The predictions can be performed for a kiln system operating only with fuel in the calciner and kiln burner, and the influence of bypass operation can be added as well as alternative fuels substitution in the kiln inlet. The sulfur release in the inlet of the rotary kiln can be minimized if the fuel combustion takes place at temperatures lower than 800 °C and can be avoided when the volatile gases from fuels are not released in contact with the bed material. 6. iv devolatilization, char combustion, the reactions between CaSO₄ and the different reducing agents, and the oxidation of the volatiles gases in the free board. The main reducing agents are CO, CH₄ and H₂, which are introduced under the bed material in the high temperature rotary drum to characterize the SO₂ release under variation of temperature, oxygen content in the gas, and time of exposure. A threshold concentration for each reducing gas, below which no SO₂ release occurs, is found. The reducing concentration and the time of exposure are of high importance for SO₂ release because it is shown that introducing the same total amount of gas, the highest reducing agent concentration for a short period released a higher total SO₂ amount compared to the lowest concentration during a long period. A mathematical reaction based model for predicting sulfur release caused by volatiles from wood particles fired in the material kiln inlet is developed and evaluated against pilot scale data, which shows that the model follows the experimental data tendency. The model can predict SO₂ release varying particle size, fill degree, and firing degree but the effect of sulfur content in the bed cannot be predicted. Further development regarding particle motion according to the rotational speed may be needed. Furthermore, a model for predicting the tendency of build-ups for a kiln system is developed based on the prediction of SO₃ and Cl concentrations in the hot meal. The predictions can be performed for a kiln system operating only with fuel in the calciner and kiln burner, and the influence of bypass operation can be added as well as alternative fuels substitution in the kiln inlet. The sulfur release in the inlet of the rotary kiln can be minimized if the fuel combustion takes place at temperatures lower than 800 °C and can be avoided when the volatile gases from fuels are not released in contact with the bed material.
Treatment of Lignin and Waste residues by Flash Pyrolysis: Final report

Lignin, sewage sludge and macroalgae (nonconventional biomasses) fast pyrolysis properties have been studied through experimental investigations on a laboratory Pyrolysis Centrifugal Reactor (PCR) and a model on lignin pyrolysis have been developed. Furthermore, the nonconventional biomass pyrolysis properties were compared with the pyrolysis properties of wood and straw. The PCR treatment of sewage sludge provides an oil that can be used for energy purposes and a solid residue rich in organic nutrients that may be used as fertilizer product. By fast pyrolysis of lignin from the IBUS ethanol plant a bio-oil can be produced with oil yields of 36% (daf) and an energy recovery of 45%. This is a relatively low bio-oil yield compared to other feedstocks, however, it may increase the value of the lignin residual product, such that the lignin char is used for combustion on the ethanol plant, and the bio-oil is sold for use on heavy oil burners. The macroalgae is a promising feedstock with a high bio-oil yield of 54 wt% daf and an energy recovery of 76% in the liquid oil. Detailed characterization of the pyrolysis products in the form of bio-oil, gas and char has been performed. The properties of slurries made of char and pyrolysis oil that potentially may be used as a feed for pressurized gasifiers has been investigated. It was shown that slurries made of mixtures of wood and bio-oil can be pumped into pressurized systems. A new patented version of the PCR rotor unit, which can be operated at low rotational speed was constructed. The new rotor systems should make it easier to make an up-scaling of the process.

A Comparison of Lignin, Macroalgae, Wood and Straw Fast Pyrolysis

A fast pyrolysis study on lignin and macroalgae (non-conventional biomass) and wood and straw (conventional biomass) were carried out in a pyrolysis centrifugal reactor at pyrolysis temperature of 550 °C. The product distributions and energy recoveries were measured and compared among these biomasses. The fast pyrolysis of macroalgae showed a promising result with a bio-oil yield of 65 wt% dry ash free basis (daf) and 76% energy recovery in the bio-oil while the lignin fast pyrolysis provides a bio-oil yield of 47 wt% daf and energy recovery in bio-oil of 45%. The physiochemical properties of the bio-oils were characterized with respect to higher heating value (HHV), molecular mass distribution, viscosity, pH, density, thermal behaviors, elemental concentrations, phase separation and aging. The lignin and macroalgae oil properties were different compared to those of the wood and straw oils with respect to carbon and oxygen contents, HHV, thermal behaviors and mean molecular weight. The HHV of wood, straw, lignin and algae oils were 24.0, 23.7, 29.7 and 25.7 MJ/kg db, respectively. The distributions of metals, Cl and S in char and bio-oil were investigated for the biomasses. Almost all the metals (Al, Ca, Fe, K, Mg, Na, P and Si) were contained in the chars at the pyrolysis temperature of 550 °C. The char properties were characterized and their potential applications are discussed.
An apparatus for conducting physical, chemical, or biological interaction between gases and solid particles

The invention provides an apparatus for conducting interaction between gases and solid particles. The apparatus has a vertical hollow shaft with a vertical row of constrictions formed internally and defining a series of intercommunicating chambers in the shaft for guiding the gas and particles e.g. in counter current to effect interaction there between, e.g. for transferring thermal energy. To enable redesign of the apparatus and to enable an improved match between need for capacity and size of the apparatus, the invention provides an apparatus where the shaft comprises a stack of separate modules arranged vertically above each other or side-by-side whereby the apparatus becomes modular.

Characterization and quantification of deposits build up and removal in straw suspension fired boilers

This project deals with ash deposit formation in suspension fired biomass power plant boilers. The project has been conducted in a tight collaboration between Vattenfall and the CHEC Research Centre at DTU Department of Chemical Engineering. A large part of the project has been performed by conducting advanced probe measurements at the Amageraerkets Vattenfall owed boilers. It was the objective of the project to provide an improved understanding of ash deposit formation and removal in biomass suspension fired boilers. The project have provided a large amount of knowledge on the following issues: 1) The influence of local boiler conditions on deposit formation in suspension fired boilers using wood or co-firing straw and wood, 2) quantification of deposit removal in biomass suspension firing boilers with regards both to natural shedding and soot blower induced shedding, 3) established relations of the properties of fuel ash, fly ash and deposits, 4) use of coal ash to remedy biomass ash induced boiler deposit problems.
CO2 Capture by Cement Raw Meal

The cement industry is one of the major sources of CO2 emissions and is likely to contribute to further increases in the near future. The carbonate looping process has the potential to capture CO2 emissions from the cement industry, in which raw meal for cement production could be used as the sorbent. Cyclic experiments were carried out in a TGA apparatus using industrial cement raw meal and synthetic raw meal as sorbents, with limestone as the reference. The results show that the CO2 capture capacities of the cement raw meal and the synthetic raw meal are comparable to those of pure limestone. The CO2 capture capacity of limestone in the raw meal is lower than for pure limestone. The difference in the CO2 capture capacity decreases with an increase in cycle number. The calcination conditions and composition are major factors that influence the CO2 capture capacity of limestone. At 850 °C in N2, the capacity of synthetic raw meal was similar to that of pure limestone, whereas at 950 °C in N2 and in a CO2-rich atmosphere there was a significant difference. The SEM and BET analyses indicate that sintering is the main reason for the lower capture capacity of the limestone in the raw meal. The main components of the raw meal used along with the limestone have different effects on the CO2 capture capacity of the limestone. Al2O3 has the most negative effect, followed by Fe2O3, whereas SiO2 showed no effect. These interactions can be observed as a correlation between the measured surface area and the CO2 capture capacity. The XRD results indicated an increase in crystallite size and the formation of new phases due to the reaction between the main components of the raw meal and the limestone, which also has an effect on the CO2 capture capacity. The formation of dicalcium silicate was also observed by XRD analysis in the calcined synthetic raw meal. The effect of calcination conditions and compositions on the CO2 capture capacity as a function of cycle number is described by a correlation equation. This equation is used to determine the decay constant (k) and residual CO2 capture capacity (Xr). This shows that raw meal could be used as a sorbent for the easy integration of the carbonate looping process into the cement pyro process for reducing CO2 emissions from the cement production process.
Co-firing of Coal with Biomass and Waste in Full-scale Suspension-fired Boilers

The energy policy in Denmark has for many years focused on lowering the net CO2 emission from heat and power production by replacing fossil fuels by renewable resources. This has been done by developing dedicated grate-fired boilers for biomass and waste fuels but also by developing coal-based suspension-fired boilers to accept still higher fractions of biomass or waste material as fuels. This last development has been challenging of many reasons, including pre-treatment of fuels, and solving potential emission and operational problems during the simultaneous development of supercritical steam cycles with steam temperatures close to 600°C, providing power efficiencies close to 50% [Hein, 2008]. For 25 years the CHEC (Combustion and Harmful Emission Control) Research Centre at DTU Chemical Engineering, has attained a leading role in research, supporting power producing industry, plant owners and boiler manufacturers to optimize design and operation and minimize cost and environmental impact using alternative fuels in suspension fired boilers. Our contribution has been made via a combination of full-scale measuring campaigns, pilot-scale studies, lab-scale measurements and modeling tools. The research conducted has addressed many issues important for co-firing, i.e. fuel processing, ash induced boiler deposit formation and corrosion, boiler chamber fuel conversion and emission formation, influence on flue gas cleaning equipment and the utilization of residual products. This paper provides an overview of research activities, aiming at increasing biomass shares during co-firing in suspension, conducted in close...
collaboration with the Danish power industry. The research has lead to an improved understanding of the alternative fuels interaction with coal in the boiler chamber. Further, the applied research has provided results with implications for operation of milling and burner equipment, appropriate fuel mixing strategies, minimization of ash deposit formation and corrosion, minimization of NO formation, appropriate operation of SCR catalyst equipment and utilization of residual products. © Tsinghua University Press, Beijing and Springer-Verlag Berlin Heidelberg 2012.
Efficient Fuel Pretreatment: Simultaneous Torrefaction and Grinding of Biomass

Combining torrefaction and grinding of biomass in one reactor may be an attractive fuel pretreatment process. A combined laboratory torrefaction and ball mill reactor has been constructed for studies of the influence of temperature and residence...
time on the product yields and particle size reductions of Danish wheat straw, spruce chips, and pine chips. On the basis of initial experiments, which evaluated the influence of reactor mass loading, gas flow, and grinding ball size and material, a standard experimental procedure was developed. The particle size reduction capability of the torrefaction process has been evaluated by the relative change in $d_{50}$, and this method was compared to the Hardgrove grindability index (HGI), showing reasonably similar results. Significant differences in torrefaction behavior have been observed for straw and spruce chips torrefied at 270–330 °C. Torrefaction of straw for 90 min yielded a higher mass loss (27–60 wt %) and relative size reduction (59–95%) compared with spruce (mass loss of 10–56 wt % and size reduction of 20–60%). The two types of biomass investigated differ with respect to hemicellulose type, lignocellulosic composition, particle morphology, and ash composition, where straw has a higher alkali content. This and other studies indicate that the large difference in the alkali contents of the biomasses is the main cause for the observed difference in torrefaction characteristics.

Experiments with separate particle heating and grinding showed a swift grinding of the torrefied biomass. This implies that the rate-limiting step in the laboratory reactor is the heat transfer and not the grinding process. Large pine particles (8–16 mm) showed a slightly higher mass loss than 4–8 and <4 mm particles. This could be the consequence of exothermic reactions in the particle core, which locally increase the temperature and conversion.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Pages: 7531–7540
Publication date: 2013
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 27
Issue number: 12
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Impact factor 2.79
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.52
Web of Science (2013): Impact factor 2.733
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.25
Web of Science (2012): Impact factor 2.853
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Experimental investigation of flash pyrolysis oil droplet combustion

The aim of this work is to investigate and compare the combustion behaviour of a single droplet of pyrolysis oil derived from wheat straw and heavy fossil oil in a single droplet combustion chamber. The initial oil droplet diameters were in between 500 μm to 2500 μm. The experiments were performed at a temperature ranging between 1000 and 1400°C with an initial gas velocity of 1.6 m/s and oxygen concentration of 3%. The evolution of combustion of bio-oil droplets was recorded by a digital video camera. It was observed that the combustion behaviour of pyrolysis oil droplet differ from the heavy oil in terms both of ignition, devolatilisation and char oxidation. The pyrolysis oil is more difficult to ignite and has a shorter devolatilisation time and a longer char oxidation time. Copyright © 2013, AIDIC Servizi S.r.l.

Fast Pyrolysis of Lignin Using a Pyrolysis Centrifuge Reactor

Fast pyrolysis of lignin from an ethanol plant was investigated on a lab scale pyrolysis centrifuge reactor (PCR) with respect to pyrolysis temperature, reactor gas residence time, and feed rate. A maximal organic oil yield of 34 wt % dry basis (db) (bio-oil yield of 43 wt % db) is obtained at temperatures of 500−550 °C, reactor gas residence time of 0.8 s, and feed rate of 5.6 g/min. Gas chromatography mass spectrometry and size-exclusion chromatography were used to
characterize the Chemical properties of the lignin oils. Acetic acid, levoglucosan, guaiacol, syringols, and p-vinylguaiacol are found to be major chemical components in the lignin oil. The maximal yields of 0.62, 0.67, and 0.38 wt % db were obtained for syringol, p-vinylguaiacol, and guaiacol, respectively. The reactor temperature effect was investigated in a range of 450–600 °C and has a considerable effect on the observed chemical components and molecular mass distribution of the lignin oils. The obtained lignin oil has a very different components composition when compared to a beech wood oil.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, DONG Energy AS
Number of pages: 9
Pages: 3802–3810
Publication date: 2013
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 27
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Impact factor 2.79
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.52
Web of Science (2013): Impact factor 2.733
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.25
Web of Science (2012): Impact factor 2.853
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 3.05
Web of Science (2011): Impact factor 2.721
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Full-Scale Continuous Mini-Reactor Setup for Heterogeneous Grignard Alkylation of a Pharmaceutical Intermediate

A reactor setup consisting of two reactors in series has been implemented for a full-scale, heterogeneous Grignard alkylation. Solutions pass from a small filter reactor into a static mixer reactor with multiple side entries, thus combining continuous stirred tank reactor (CSTR) and plug flow reactor (PFR) technologies. Through the use of the reactor train in combination with in-line NIR analysis, on scale a 35% reduction in solvent volume was realized, and the formation of a key impurity was suppressed. The mini-reactor solution achieved many of the economic advantages attributed to microreactor technology, while avoiding the difficulties associated with handling of solids in microreactors.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Department of Applied Chemistry, H. Lundbeck A/S
Pages: 1142-1148
Publication date: 2013
Peer-reviewed: Yes

Publication information
Journal: Organic Process Research and Development
Volume: 17
Issue number: 9
ISSN (Print): 1083-6160
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.95 SJR 1.405 SNIP 0.978
Web of Science (2017): Impact factor 3.584
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.48 SJR 1.068 SNIP 0.85
Web of Science (2016): Impact factor 2.857
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.54 SJR 1.301 SNIP 1.01
Gas-Solid Heat Exchanger for Cement Production

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, CAPEC-PROCESS, FLSmidth & Co. A/S

DOI: 10.1021/op400069e
Source: dtu
Source-ID: n:oai:DTIC-ART:acs/390408497::34635
Research output: Research - peer-review ; Journal article – Annual report year: 2013

Web of Science (2015): Impact factor 2.922
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.38 SJR 1.033 SNIP 0.982
Web of Science (2014): Impact factor 2.528
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.44 SJR 1.135 SNIP 0.967
Web of Science (2013): Impact factor 2.549
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.32 SJR 1.203 SNIP 1.128
Web of Science (2012): Impact factor 2.739
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 2.22 SJR 1.213 SNIP 0.909
Web of Science (2011): Impact factor 2.391
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.12 SNIP 0.965
Web of Science (2010): Impact factor 2.207
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.063 SNIP 0.924
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.955 SNIP 0.926
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.017 SNIP 0.944
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.093 SNIP 0.889
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.862 SNIP 0.817
Scopus rating (2004): SJR 0.708 SNIP 0.797
Scopus rating (2003): SJR 0.436 SNIP 0.658
Scopus rating (2002): SJR 0.595 SNIP 0.841
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.623 SNIP 0.742
Scopus rating (2000): SJR 0.332 SNIP 0.732
Scopus rating (1999): SJR 0.529 SNIP 0.639
Original language: English
Influence of Biomass Chemical Properties on Torrefaction Characteristics

Different biomass types may differ with respect to torrefaction characteristics, and an improved understanding and ability to predict the torrefaction performance is, therefore, desired. In this study, the influence of the chemical properties (lignocellulose composition and alkali content) on the torrefaction behavior with respect to mass loss and grindability is investigated by simultaneous thermal analysis (STA) and by using a combined torrefaction and grinding reactor. The torrefaction behavior of six raw biomass samples and selected pretreated samples (washed and impregnated with KCl and K2CO3) has been studied. The investigated biomasses have reasonably similar carbohydrate compositions (hemicelluloses 18–25 wt % db; cellulose 38–48 wt % db; lignin 17–29 wt % db) with the exception of spruce bark, which is lower in hemicellulose content (12.9 wt % db) and cellulose content (24 wt % db), and higher in lignin content (36.8 wt % db). An increasing biomass potassium (K) content decreases the temperature of maximal conversion for both raw and alkali-impregnated biomass samples, thus decreasing the solid product yield at 270 and 300 °C. This was especially pronounced when the biomass potassium content increased from 0 to 0.2 wt %. However, the higher lignin content in bark causes a higher solid yield than what would be expected from the alkali content, illustrating that both potassium content and lignocellulose composition affect the solid yield obtained by torrefaction. The grindability of the torrefied products was evaluated by determining the d50 value of the particle size distribution of the biomass before and after torrefaction in the combined torrefaction and mill reactor. A significant decrease in d50 value was observed when the alkali content increased from 0 to 0.2 wt % db, whereas no additional effect is seen for higher potassium contents.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Number of pages: 8
Pages: 7541-7548
Publication date: 2013
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 27
Issue number: 12
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Influence of the Pyrolysis Temperature on Sewage Sludge Product Distribution, Bio-Oil, and Char Properties

Fast pyrolysis may be used for sewage sludge treatment with the advantages of a significant reduction of solid waste volume and production of a bio-oil that can be used as fuel. A study of the influence of the reaction temperature on sewage sludge pyrolysis has been carried out using a pyrolysis centrifugel reactor (PCR) at 475, 525, 575, and 625 °C. Maxima of both organic oil yield of 41 wt % on a dry ash free feedstock basis (daf) and a sludge oil energy recovery of 50% were obtained at 575 °C. The water-insoluble fraction, molecular-weight distribution, higher heating value (HHV), and thermal behaviors of sludge oils were found to be considerably influenced by the applied pyrolysis temperatures. The sludge oil properties obtained at the optimal temperature of 575 °C were a HHV of 25.5 MJ/kg, a water-insoluble fraction of 18.7 wt %, a viscosity of 43.6 mPa s at 40 °C, a mean molecular weight of 392 g/mol, and metal concentrations lower than 0.14 wt % on a dry basis (db). Less optimal oil properties with respect to industrial applications were observed for oil samples obtained at 475 and 625 °C. Char properties of the 575 °C sample were an ash content of 81 wt % and a HHV of 25.5 MJ/kg db. A total of 95% of the sewage sludge phosphorus content was recovered in the char. The solid waste amount (char compared to sludge) was reduced to 52% on a bulk volume basis at the pyrolysis temperature of 575 °C.

General information
State: Published
Investigation of char strength and expansion properties of an intumescent coating exposed to rapid heating rates

An efficient and space saving method for passive fire protection is the use of intumescent coatings, which swell when exposed to heat, forming an insulating char layer on top of the virgin coating. Although the temperature curves related to so-called cellulosic fires are often referred to as slow heating curves, special cases where the protective char is mechanically damaged and partly removed can cause extremely fast heating of the coating. This situation, for a solvent based intumescent coating, is simulated using direct insertion of free films into a muffle oven. The char formed is evaluated with respect to the mechanical resistance against compression, degree of expansion, and residual mass fraction. Experimental results show that when using this type of shock heating, the mechanical resistance of the char against compression cannot meaningfully be correlated to the expansion factor. In addition, char properties, measured at room temperature, were dependent on the preceding storage conditions (in air or in a desiccator). The char was found to have the highest mechanical strength against compression in the outer crust facing the heat source. For thin (147μm) free coating films, a tendency to contract in the horizontal plane was observed. The experimental approach is relevant for testing of intumescent coatings used in buildings where moving or falling objects may damage the char during a fire.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Hempel A/S
Contributors: Nørgaard, K. P., Dam-Johansen, K., Català, P., Kiil, S.
Pages: 1851-1857
Publication date: 2013
Peer-reviewed: Yes

Publication information
Journal: Progress in Organic Coatings
Volume: 76
Issue number: 12
ISSN (Print): 0300-9440
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): SJR 0.844 SNIP 1.288
Web of Science (2017): Impact factor 2.955
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.89 SJR 0.852 SNIP 1.335
Web of Science (2016): Impact factor 2.858
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.84 SJR 0.857 SNIP 1.384
Web of Science (2015): Impact factor 2.632
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.8 SJR 0.997 SNIP 1.585

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Norwegian University of Science and Technology, Åbo Akademi University, Graz University of Technology
Separation of enantiomers by continuous preferential crystallization: Experimental realization using a coupled crystallizer configuration

The experimental realization of a continuous preferential crystallization process, consisting of two mixed-flow crystallizers coupled via crystal-free liquid exchange streams and with only the liquid phases operating continuously, is addressed. Experiments in triplicate, using the conglomerate-forming system of dl-asparagine monohydrate in water, were conducted, and the achievement of nearly racemic composition of the liquid phase in the crystallizers was verified. An experiment was also carried out using seed crystals of a smaller average particle size than used in the reference experiments. Successful enantioseparation by crystal growth, with the repeatability being within ±10% deviation, was obtained. However, slow crystal growth, due to a low surface integration rate, led to a negligible consumption of the desired enantiomer added in the feed solution, resulting in low productivities. Productivities, yields, and purities of solid products were influenced by the morphological differences in the seed crystals. Due to irregularly shaped seed crystals, increase in the productivities and yields were achieved in the L-Tank. Lower purities of solid products from the L-Tank compared to purities of the solid products from the D-Tank were obtained. This could be due to surface nucleation of d-asparagine monohydrate, ascribed to the surface structure of the seeds of l-asparagine monohydrate supplied. Improvements in productivity, yield, and purity in the L-Tank, for the same process duration, were realized using seed crystals of lower average particle size having a smoother surface structure. The main advantages compared to other separation processes are low capital cost, high crystal purity and yield, ease of upscaling, increased safety, and reduced environmental impact due to reduction in the amount of solvent used. The application is currently limited to conglomerate-forming systems, but the separation concept may open new possibilities for process improvements regarding enantioseparation of racemic compound-forming systems as well. © 2013 American Chemical Society.
Torrefaction of biomass for power production

In order to increase the share of biomass for sustainable energy production, it will be an advantage to utilize fuels as straw, wood and waste on large suspension fired boilers. On a European scale, currently large straw resources are available that are not fully utilized for energy production. Straw can be co-fired with coal in suspension fired power plants with a maximum straw share of 10 to 20 wt%. However, 100% straw firing induced several problems that can impede both boiler availability and power efficiency. Straw is highly fibrous and tenacious in nature, therefore a relatively high amounts
of energy is needed to pulverize the straw to a size where a good burn out can be obtained. Also the large alkali and chlorine content in straw often induce severe chlorine rich deposit formation on super heaters. The chlorine rich deposits are corrosive and to prevent high superheater corrosion rates, relatively low superheater temperatures have to be applied, which in turn lower the power efficiency.

The idea for this Ph.D. project is to develop a biomass pretreatment method that could provide the heating value of the fuel for the boiler, but in a way such that the fuel is easily pulverized and the superheating can be done without an exposure of alkali rich flue gas on superheaters. A potential pretreatment process is to use a ball mill with an integrated torrefaction process. The char produced is very fragile and can be easily pulverized down to a size where a high burn out is obtained. The present Ph.D. thesis focus on the following subjects: 1) the development of experimental procedures for a novel laboratory scale reactor (simultaneous torrefaction and grinding) and a study on the torrefaction of straw and wood; 2) study the influence of biomass chemical properties such as ash content, ash composition and carbohydrate composition on torrefaction characteristics by using a broader range of biomasses; and 3) quantification of chlorine and sulfur release during torrefaction.

A novel laboratory scale experimental setup which combines torrefaction and a ball mill has been constructed for studies of the influence of feedstock type, temperature and residence time on the product yields and particle size reductions. The laboratory set up was used to investigate the torrefaction properties of Danish wheat straw and spruce chips. A standard experimental procedure was developed based on initial experiments which evaluated the influence of reactor mass loading, gas flow and grinding ball size and material. The particle size reduction capability of the torrefaction process has been evaluated by using the relative change in d50 of the product size distribution, and this method was compared with the Hardgrove Grindability Index (HGI), showing reasonably similar results.

Significant differences in torrefaction behavior have been observed for straw and spruce chips torrefied at 270 – 330 °C. Torrefaction of straw for 90 minutes yielded a higher mass loss (27 – 60 wt %) and a larger relative size reduction (59 – 95%) compared to spruce (mass loss of 10 – 56 wt% and a size reduction of 20 – 60%). The two types of biomass investigated differ with respect to hemicellulose type, lignocellulosic composition, particle morphology and ash composition where straw has higher alkali content. Experiments with separate particle heating and grinding showed a swift grinding of the torrefied biomass which implies that the rate limiting step in the laboratory reactor is the heat transfer, and not the grinding process.

Different torrefaction characteristics are observed from straw and wood chips, therefore an improved understanding and ability to predict the torrefaction characteristic of different biomass types are desired. In this study, the influence of biomass chemical properties (carbohydrate composition and alkali content) on the torrefaction behavior with respect to mass loss and grindability is investigated. Six raw biomass samples (Danish wheat straw, miscanthus, spruce, beech, pine, and spruce bark) with different chemical and physical properties were pyrolyzed by Simultaneous Thermal Analysis (STA) and torrefied in the simultaneous torrefaction and grinding reactor. The effect of biomass alkali content on torrefaction characteristics were furthermore investigated by washing or impregnating (KCl and K2CO3) of selected biomass. The solid yields at the investigated torrefaction temperatures (270 and 300 °C) are strongly influenced by the biomass potassium content as well as to some extent the lignocelluloses composition. High biomass potassium content leads to a relatively low solid yield; however in a single case (spruce bark), a high lignin content leads to a relatively high solid yield even in the presence of relatively high potassium content. In summary both potassium content and lignocelluloses composition affect the solid yield obtained by torrefaction. A significant decrease in d50 value of the torrefied products was observed when the alkali content is increased from 0 to 0.2 wt% db, while no additional effect is seen for higher potassium contents.

The release of chlorine (Cl) and sulfur (S) to gas phase during biomass torrefaction has been investigated via experiments in laboratory-scale reactors by using six biomasses which cover a wide range of ash content and ash-forming elements in the temperature range of 150 – 500 °C. The relative release of chlorine and sulfur was calculated based on mass balance and analysis of the biomass before and after torrefaction. In few cases, measurement of methyl chloride (CH3Cl) in the gas released from straw torrefaction has been conducted. Initial release of chlorine was observed at 250 °C and about sixty percent of chlorine was released from straw at 350 °C. The analysis of methyl chloride from the released gas showed that most of chlorine was released as CH3Cl. By using a large amount of straw (40 g compared to 5 – 20 g), less Cl is released, probably due to more reactive sites available for secondary reactions. The secondary reactions can be reaction with relatively stable basic functionalities on the char surface or reaction with potassium to generate KCl. Almost complete release of chlorine was observed for woody biomass at 350 °C. This result showed an agreement with the previous studies reported that the biomass with a lower chlorine content released a higher fraction of chlorine during the pyrolysis process. Significant sulfur release (about 60%) was observed from the six biomasses investigated at 350 °C. It is seen that the initial sulfur content in biomass did not influence the fraction of sulfur release during torrefaction.

**General information**

State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Saleh, S. B., Dam-Johansen, K., Jensen, P. A., Hansen, B. B.
Number of pages: 137
Publication date: 2013

**Publication information**

Publisher: Technical University of Denmark, Department of Chemical and Biochemical Engineering
Original language: English
Electronic versions:
Trace elements in co-combustion of solid recovered fuel and coal

Trace element partitioning in co-combustion of a bituminous coal and a solid recovered fuel (SRF) was studied in an entrained flow reactor. The experiments were carried out at conditions similar to pulverized coal combustion, with SRF shares of 7.9 wt.% (wet basis), 14.8 wt.% and 25.0 wt.% In addition, the effect of additives such as NaCl, PVC, ammonium sulphate, and kaolinite on trace element partitioning was investigated. The trace elements studied were As, Cd, Cr, Pb, Sb and Zn, since these elements were significantly enriched in SRF as compared to coal. During the experiments, bottom ash was collected in a chamber, large fly ash particles were collected by a cyclone with a cut-off diameter of ~2.5 μm, and the remaining fly ash particles were gathered in a filter. It was found that when coal was co-fired with SRF, the As, Cd, Pb, Sb and Zn content in filter ash/cyclone ash increased almost linearly with their content in fuel ash. This linear tendency was affected when the fuels were mixed with additives. The volatility of trace elements during combustion was assessed by applying a relative enrichment (RE) factor, and TEM–EDS analysis was conducted to provide qualitative interpretations. The results indicated that As, Cd, Pb, Sb and Zn were highly volatile when co-firing coal and SRF, whereas the volatility of Cr was relatively low. Compared with coal combustion, co-firing of coal and SRF slightly enhanced the volatility of Cd, Pb and Zn, but reduced the volatility of Cr and Sb. The Cl-based additives increased the volatility of Cd, Pb and As, whereas addition of ammonium sulphate generally decreased the volatility of trace elements. Addition of kaolinite reduced the volatility of Pb, while the influence on other trace elements was insignificant. The results from the present work imply that trace element emission would be significantly increased when coal is co-fired with SRF, which may greatly enhance the toxicity of the dusts from coal-fired power plant. In order to minimize trace element emission in co-combustion, in addition to lowering the trace element content in SRF, utilizing SRF with low Cl content and coal with high S and aluminosilicates content would be desirable.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, DONG Energy AS
Pages: 212-221
Publication date: 2013
Peer-reviewed: Yes

Publication information
Journal: Fuel Processing Technology
Volume: 105
ISSN (Print): 0378-3820
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.46 SJR 1.453 SNIP 1.729
Web of Science (2017): Impact factor 3.956
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.15 SJR 1.397 SNIP 1.729
Web of Science (2016): Impact factor 3.752
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.09 SJR 1.501 SNIP 1.817
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.96 SJR 1.612 SNIP 2.167
Web of Science (2014): Impact factor 3.352
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.83 SJR 1.61 SNIP 2.121
Web of Science (2013): Impact factor 3.019
Acceleration of pharmaceutical production by using micro-reactor technology in a continuous mode

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Center for Process Engineering and Technology, CHEC Research Centre, Computer Aided Process Engineering Center, H. Lundbeck A/S
Contributors: Mitic, A., Cervera Padrell, A. E., Skovby, T., Kill, S., Gani, R., Dam-Johansen, K., Gernaey, K.
Number of pages: 2
Publication date: 2012
Peer-reviewed: Yes
Electronic versions:
MITIC_IMRET12_oral.pdf
Application of Carbonate Looping to Cement Industry

In the present work, cycle experiments of different types of limestone, cement raw meal and a mixture of limestone and clay were carried out in laboratory scale setups at more realistic conditions (i.e. calcination temperature is 950°C and CO2 concentration is 80%) to simulate the performance of sorbents in carbonate looping processes. The results show that the CO2 carrying capacity of limestone is much lower at realistic conditions than at mild conditions, which are often used in laboratory experiments. BET and SEM analyses show that the surface area of calcined limestone decreases significantly with an increase in the CO2 partial pressure during calcination, indicating enhancement of sintering by the presence of CO2. As sorbents, cement raw meal and the mixture of limestone and clay show a similar trend as limestone with respect to the decay of the CO2 carrying capacity and this capacity is lower than that of limestone at the same conditions in most cases. SEM and XRD analyses indicate that a combination of severe sintering and formation of calcium silicates attributes to the poor performance of the cement raw meal.

Ash transformation and deposit build-up during biomass suspension and grate firing: Full-scale experimental studies

An attractive option for reducing the net CO2 emissions is to substitute coal with biomass in large power plant boilers. However, the presence of chlorine (Cl) and alkali metals (K, Na) in biomass may induce large operational problems due to ash deposit formation on the superheater tubes. The aim of this study was to investigate ash transformation and deposition behavior in two biomass-fired boilers, firing wheat straw and/or wood. The influence of straw firing technology (grate and suspension) on the ash transformation, deposit formation rate and deposit characteristics has been investigated. Bulk elemental analysis of fly ashes revealed that fly ash from suspension firing of straw has high contents of Si, K and Ca, while fly ash from straw firing on grate was rich in the volatile elements K, Cl and S. Investigations of deposit formation rates were made in the superheater and convective pass regions of the boilers by use of an advanced online deposit probe. During straw firing on grate, the measured deposit formation rate was close to 38 g/m²/h. Data from straw suspension firing showed a deposit formation rate of 41 g/m²/h. The deposit formation rates during straw suspension firing and straw grate firing were on similar levels. This was observed even though the concentration of fly ash in the flue gas was significantly higher during straw suspension firing. The influence of co-combustion of wood with straw on deposit formation rate, probe heat uptake and deposit characteristics was also investigated during suspension firing conditions. Data from 35% straw suspension firing with wood showed a deposit formation rate of 33 g/m²/h for the first 12 h. The deposit formation rate increased to 41 g/m²/h with 100% straw firing. The probe heat uptake reduction up to 40 h of exposure time was 3.0, 7.3, 8.4 and 16.5 kW/m² during 35, 65, 80 and 100% straw firing, respectively.
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.46 SJR 1.453 SNIP 1.729
Web of Science (2017): Impact factor 3.956
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.15 SJR 1.397 SNIP 1.729
Web of Science (2016): Impact factor 3.752
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.09 SJR 1.501 SNIP 1.817
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.96 SJR 1.612 SNIP 2.167
Web of Science (2014): Impact factor 3.352
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.83 SJR 1.61 SNIP 2.121
Web of Science (2013): Impact factor 3.019
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.77 SJR 1.644 SNIP 2.055
Web of Science (2012): Impact factor 2.816
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 3.38 SJR 1.544 SNIP 1.781
Web of Science (2011): Impact factor 2.945
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.599 SNIP 1.884
Web of Science (2010): Impact factor 2.781
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.531 SNIP 1.851
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.451 SNIP 1.756
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.218 SNIP 1.72
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.975 SNIP 1.454
Scopus rating (2005): SJR 0.748 SNIP 1.152
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.807 SNIP 1.239
Scopus rating (2003): SJR 0.907 SNIP 1.151
Scopus rating (2002): SJR 0.689 SNIP 1.106
Scopus rating (2001): SJR 0.568 SNIP 0.971
Scopus rating (2000): SJR 1.23 SNIP 0.999
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 1.169 SNIP 1.074
Ash transformation and deposition behavior during co-firing biomass with sewage sludge
In the present work, the ash transformation and deposition behavior during wheat straw and wood waste combustion were investigated by combustion experiments in an entrained flow reactor. The influence of sewage sludge addition on ash chemistry and deposition tendency was also studied. During combustion wheat straw, fine fly ash particles smaller than 2.5 μm are mainly formed due to vaporization, nucleation and condensation of K, Cl, S and P species. Large fly ash particles consist of condensed potassium chloride crystals and molten/partial molten spherical particles rich in K-silicates and K-Ca-silicates. The deposits formed on a well-controlled sampling probe are dominated by molten particles rich in K silicates. Over 70% of K in the fly ash is water soluble. The fine fly ash from wood waste combustion consists of mainly KCl and NaCl.

Both ash clusters and molten spherical particles are found from the ash deposits, which mainly contain K-silicates, K-Al-silicates and K-Ca-silicates. The sewage sludge addition significantly reduced the water soluble K and Na in the fly ash from wheat straw and wood waste combustion. Compared to pure wheat straw and wood waste, the ash deposition rates were increased due to sewage sludge addition. However, the ash deposition propensity decreased significantly. In addition, the content of water soluble K and Cl in the deposits reduced as a result of sewage sludge addition. The results from present work suggest co-firing of sewage sludge could alleviate deposit formation during suspension firing of risky biofuels.

Bio-oil from Flash Pyrolysis of Agricultural Residues
This thesis describes the production of bio-oils from flash pyrolysis of agricultural residues, using a pyrolysis centrifugal reactor (PCR). By thermal degradation of agricultural residues in the PCR, a liquid oil, char and non-condensable gases are produced. The yield of each fraction is influenced by the reaction temperature and by feedstock ash composition. It have been the objective of the present work to investigate the influence of changed operation conditions on the yield of bio-oil, char and gas; as well as to investigate the composition and storage properties of some of the produced bio-oils. Mainly the influence of feedstock type (wheat straw, rice husk and pine wood), feedstock water content and reactor temperature on the yield of char, bio-oil and gas were investigated. The storage stability of bio-oils with respect to changes in viscosity, water content and pH were investigated for straw and pine wood oil at different temperature and residence times.

Temperature plays a major role in the pyrolysis process and it determines to a high degree the fate of the final product yields and also product composition. Higher temperature favors the formation of pyrolysis gas while lower temperatures increase the yield of char. Liquid oil, however increases with temperature up to certain point and thereafter it decreases at still higher temperature due to secondary cracking of the primary products. The presence of moisture in the feed stock may also influences the pyrolysis process. The influence of reaction temperature and the moisture content on the flash pyrolysis product yield has been reported in Paper I (Chapter 2). It was observed that the presence of moisture in the wheat straw with different moisture levels of 1.5 wt. %, 6.2 wt. % and 15.0 wt. % have shown no significant effect on the pyrolysis product distribution. The fraction of bio-oil, char and gases produced from pyrolysis of straw were in the range of 40-60 wt. %, 18-50 wt. % and 5-22 wt. %, respectively, regardless of the straw moisture levels. The optimal reaction temperature for the production of bio-oil was around 525 °C to 550 °C for all straw moisture contents.

It was investigated how differences in biomass composition influence pyrolysis products yields and the composition of char and bio-oils. Details about this investigation are explained in Paper II (Chapter 3). The used pine wood had a low ash content (0.5 wt. %), the wheat straw an intermediate ash level (6.0 wt. %) and the rice husk a high ash level (13.6 wt. %). The highest alkali content, potassium (1.53 wt. %) are present in straw and the lowest potassium content level is observed
in pine wood (0.04 wt. %). The feedstocks were pyrolyzed at reactor temperatures ranging from 475 to 575 °C. It was observed that the formation of char and gas is affected by the biomass alkali content. Increasing biomass alkali content caused an increased feedstock conversion at low temperature, a lower maximum liquid organic yield temperature and a lower maximum liquid organics yield. In addition, the chemical compositions of the bio-oils and the chars of the investigated feedstocks were also analyzed.

The utilization of the pyrolysis oil in static combustion equipments such as boilers and turbine have shown that the suitability of the pyrolysis oil to substitute fossil fuel. However, several limitations still arise due to the instability of the pyrolysis oil that may cause problems with transport and storage. Pyrolysis oil contains more than hundred of chemical compounds and has a wide range of volatility (different boiling points). The stability and aging of bio-oils generated by bench scale pyrolysis of wheat straw and pine wood are discussed in Paper III (Chapter 4). It was found that the bio-oil from wheat straw shows better stability compared to the bio-oil from pine wood. In addition, both bio-oils are fairly stable stored in a closed container at room temperature for up to 130 days, with no phase separation and only small changes in physical properties were observed.

The combustion behavior of pyrolysis oils derived from wheat straw and pine wood are investigated and discussed in Paper IV (Chapter 5). The investigation is done in two parts. In the first part, the technique of thermogravimetric analysis (TGA) was applied to study the thermal treatment of the pyrolysis oils under well controlled temperature in an oxidative (O2) and non-oxidative (N2) environment. It was found that the drying phase occurred below 200 °C, evaporation of light components and cracking of heavy fractions occurs at the temperature above 200 up to 500 °C, and finally the char combustion occurs at temperatures above 500 up to 700 °C. In the second part, the combustion of single droplets of pyrolysis oils were investigated and compared with the heavy fossil fuel oil by making experiments in a single droplet pyrolysis combustion chamber. The initial oil droplet diameters were in between 500 μm to 2500 μm. The experiments were performed at a temperature ranging between 1000 and 1400 °C with an initial gas velocity of 1.6 m/s and oxygen concentration of 3%. It was observed that the burning of bio-oil droplet experienced large swelling with swelling factors up to 4 times of the initial droplet diameter. However, the burning of heavy fossil fuel oil droplet showed neither swelling nor bubbling. In addition, the droplet burning lifetimes for bio-oils (droplet size of 1500 μm at a temperature of 1000 °C were found to be longer (13 s and 9 s for straw oil and wood oil, respectively) than the heavy oil (6 s) at the temperature of 1200 °C. It can be concluded that the combustion of bio-oils droplet are different from the combustion of heavy fossil fuel oil in terms of ignition, devolatilisation and char combustion. The bio-oil is difficult to ignite and has a shorter devolatilisation time and a longer char combustion time.
Volume: 51  
ISSN (Print): 0888-5885  
Ratings:  
BFI (2019): BFI-level 2  
Web of Science (2019): Indexed yes  
BFI (2018): BFI-level 2  
Web of Science (2018): Indexed yes  
BFI (2017): BFI-level 2  
Scopus rating (2017): CiteScore 3.4 SJR 0.978 SNIP 1.203  
Web of Science (2017): Impact factor 3.141  
Web of Science (2017): Indexed yes  
BFI (2016): BFI-level 2  
Scopus rating (2016): CiteScore 3.1 SJR 0.95 SNIP 1.155  
Web of Science (2016): Impact factor 2.843  
Web of Science (2016): Indexed yes  
BFI (2015): BFI-level 2  
Scopus rating (2015): CiteScore 2.87 SJR 0.938 SNIP 1.145  
Web of Science (2015): Impact factor 2.567  
Web of Science (2015): Indexed yes  
BFI (2014): BFI-level 2  
Scopus rating (2014): CiteScore 2.85 SJR 1.009 SNIP 1.287  
Web of Science (2014): Impact factor 2.587  
Web of Science (2014): Indexed yes  
BFI (2013): BFI-level 2  
Scopus rating (2013): CiteScore 2.6 SJR 0.975 SNIP 1.232  
Web of Science (2013): Impact factor 2.235  
ISI indexed (2013): ISI indexed yes  
Web of Science (2013): Indexed yes  
BFI (2012): BFI-level 2  
Scopus rating (2012): CiteScore 2.56 SJR 1.054 SNIP 1.32  
Web of Science (2012): Impact factor 2.206  
ISI indexed (2012): ISI indexed yes  
Web of Science (2012): Indexed yes  
BFI (2011): BFI-level 2  
Scopus rating (2011): CiteScore 2.58 SJR 1.076 SNIP 1.236  
Web of Science (2011): Impact factor 2.237  
ISI indexed (2011): ISI indexed yes  
Web of Science (2011): Indexed yes  
BFI (2010): BFI-level 2  
Scopus rating (2010): SJR 1.049 SNIP 1.161  
Web of Science (2010): Impact factor 2.072  
Web of Science (2010): Indexed yes  
BFI (2009): BFI-level 2  
Scopus rating (2009): SJR 1.001 SNIP 1.156  
Web of Science (2009): Indexed yes  
BFI (2008): BFI-level 2  
Scopus rating (2008): SJR 1.14 SNIP 1.255  
Web of Science (2008): Indexed yes  
Scopus rating (2007): SJR 1.106 SNIP 1.233  
Web of Science (2007): Indexed yes  
Scopus rating (2006): SJR 1.035 SNIP 1.209  
Web of Science (2006): Indexed yes  
Scopus rating (2005): SJR 0.992 SNIP 1.231
Characterization and Quantification of Deposit Build-up and Removal in Straw Suspension-Fired Boilers - Ph.d. thesis
Muhammad Shafique Bashir

An increased use of biomass in large suspension-fired power plants can be a relatively economic and potentially also efficient way to utilize biomass for heat and power production. However, large deposit formation problems limit the electrical efficiency by limiting the maximum applicable superheater temperature, and the deposits may also cause boiler stops where different parts of the boiler have to be cleaned. This project aims at providing scientically based knowledge on understanding of ash deposit formation and shedding in biomass suspension-fired boilers. Deposit probe measurements have been conducted in different biomass suspension-fired boilers by using advanced ash deposition probes. Two kinds of ash deposition probes have been used. A horizontal probe that has been developed further, which can register probe temperature, deposit mass uptake, heat uptake and video monitoring. First steps have also been taken for the development of a vertical probe that was employed for ash deposition measurements on a boiler furnace wall.

In the first series of probe measurements, the influence of straw ring technology (grate and suspension) on ash transformation, deposit formation rate and deposit characteristics has been investigated. Full-scale probe measurements were conducted at a 250 MWth suspension boiler, ring straw and wood in suspension, and the results were compared with measurements conducted at a 105 MWth straw-grate boiler. Bulk elemental analysis of fly ashes revealed that fly ash from suspension ring of straw has high contents of Si, K and Ca, while fly ash from straw grate ring was rich in the volatile elements, K, Cl and S. SEM-EDS analysis showed that the fly ash from straw suspension ring consists of three kinds of particles: 1) flake type Si rich particles, 2) molten or partially molten particles (> 20 μm) rich in Si, K and Ca with small amounts of Mg, P, and potassium salts on the outer surface, and 3) small particles rich in K, Cl and S (aerosols, between 0.1 and 5 μm). Ash deposition data were compared with data from previously conducted deposit probe measurements in biomass-grate boilers. The comparison showed an increasing trend in deposit formation rate with increase in fuel gas temperature. At a fuel gas temperature of 650 °C, the deposit formation rate is typically from 5 to 30 g/m²/h and at 900 °C, the deposit formation rate is typically 20 to 110 g/m²/h. At higher fuel alkali contents (K > 0.9 wt.%), the increase in deposit formation rate was more significant, compared to the increase in deposit formation rate at lower fuel alkali contents (K < 0.9 wt.%). An increased fuel gas temperature probably increases the fraction of molten ash as well as provides an increased content of gas phase alkali species, and both will lead to an increased deposit formation rate. The deposit formation rates during straw suspension ring and straw grate ring were on similar levels. This was observed even though the concentration of fly ash in the fuel gas was higher during straw suspension ring.

The objective of the second probe measuring series was to investigate the influence of fuel type (straw share in wood), probe exposure time, probe surface temperature (500 °C, 550 °C and 600 °C), and fuel gas temperature (600-1050 °C) on the transient deposit build-up and shedding in a 350 MWth suspension boiler, ring straw and wood. Two different measures of deposit formation rate are used in the analysis of the data. The first is the integral deposit formation rate (IDF-rate) found by dividing the integral mass change over integral time intervals (of order several hours) by the time interval. The IDF-rate is then the result of both the deposit formation rate and shedding events in a given period. In this work IDF-rates were determined using 12 h intervals. The IDF-rate is similar to deposit formation rates determined from previous full-scale measuring data. A second measure, the derivative-based deposit formation rate (DDF-rate), was...
A new lab-scale setup rotary kiln simulator (RKS) was designed and built for this purpose. It is assembled of two parts: an

to derive knowledge on gradual clinker property development, as a function of different process parameters.

simulate the industrial clinker burning process on a laboratory scale and to conduct clinker formation experiments in order

to improve clinker quality (and output), we need a

to increase the profitability of cement production. These changes also affect the core of the entire cement producing process:

Clinker Burning Kinetics and Mechanism

The industrial cement process is subject to several changes in order to reduce the high energy consumption and thereby

increase the profitability of cement production. These changes also affect the core of the entire cement producing process:

the clinker formation in the rotary kiln. Thus, in order to maintain or even improve clinker quality (and output), we need a

better understanding of the development of clinker properties inside the kiln to react upon the impact of process changes.

Clinker formation in industrial rotary kilns is very complex due to a vast number of interacting parameters: kiln dimensions,

rotation velocity, temperature, gas composition, heat transfer phenomena, etc. These conditions can only be partly

simulated in ordinary lab-scale experiments. Thus, the objectives of this project have been to establish test equipment to

simulate the clinker formation in the rotary kiln. Thus, in order to maintain or even improve clinker quality (and output), we need a

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Clinker formation in industrial rotary kilns is very complex due to a vast number of interacting parameters: kiln dimensions,

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simulate the industrial clinker burning process on a laboratory scale and to conduct clinker formation experiments in order

to derive knowledge on gradual clinker property development, as a function of different process parameters.

A new lab-scale setup rotary kiln simulator (RKS) was designed and built for this purpose. It is assembled of two parts: an
ordinary lab-scale heating furnace and a sample motion system. The motion system consists of a SiC tube, which moves the sample, placed in a Pt/Rh-crucible, at a chosen velocity through the heating furnace. Simultaneously, the sample is rotated around its horizontal axis with a chosen rotation velocity. The heating furnace consists of five individual heating zones, which are set to obtain a temperature ramp from ~900-1540 °C. Furthermore, the atmosphere in the system can be set to any mixture of N2, O2 and CO2. Thus, the rotary kiln simulator features most important parameters of the industrial cement rotary kiln (ICRK): gradual temperature increase, rotation velocity and gas phase composition.

An investigation of clinker formation vs. heating profile and rotational velocity were conducted, and the influence on the clinker phase composition and clinker agglomeration was deduced. Independent of the raw meal used, the different clinker phases were formed in three stages: 1. C2S, C3A and C4AF formation at ~900-1350 °C; 2. Clinker melt formation at ~1350-1400 °C; and 3. C3S formation at >1350 °C. The first temperature of clinker melt occurrence varied slightly depending on the type of raw meal used.

The establishment of the RKS setup will allow more realistic clinker formation studies in future and thus potentially an experimental lab-scale access to the understanding of important parameters in the ICRK. The obtained qualitative and quantitative data on clinker phase composition and on agglomerate formation depend on operational parameters and are essential for the development/improvement of models for bed material process in the ICRK, and for the development steps to improve the reactor technology.

**General information**

State: Published
Organisations: Department of Chemical and Biochemical Engineering, FLSmidth & Co. A/S
Contributors: Telschow, S., Dam-Johansen, K., Jappe Frandsen, F., Wedel, S., Theisen, K.
Number of pages: 179
Publication date: 2012

**Publication information**

Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark (DTU)
Original language: English
Electronic versions: PhD_thesis_Samira_Telschow..PDF
Research output: Research › Ph.D. thesis – Annual report year: 2012

**Combustion of large solid fuels in cement rotary kilns**

The cement industry has a significant interest in replacing fossil fuels with alternative fuels in order to minimize production costs and reduce CO2 emissions. These new alternative fuels are in particular solid fuels such as refuse derived fuel (RDF), tire-derived fuel (TDF), meat and bone meal (MBM), waste wood, sewage sludge, paper and plastics. The alternative fuel share of the total energy varies significantly from region to region, but the general trend is towards increased alternative fuel utilization. Solid alternative fuels typically have physical and chemical properties that differ from traditional solid fossil fuels. This creates a need for new combustion equipment or modification of existing kiln systems, because alternative fuels may influence process stability and product quality. Process stability is mainly influenced by exposing the raw material bed in the rotary kiln to reducing conditions, which increases the tendency for deposit formations in the rotary kiln material inlet end, kiln riser duct and lower cyclone stages. Clinker quality may also be affected by minor compounds from the fuel ashes or from unburned carbon leaving the rotary kiln with the clinker.

This thesis provides an insight into the utilization of solid alternative fuels in the material inlet end of rotary kilns. This position is interesting because it allows utilization of large fuel particles, thereby eliminating the need for an expensive shredding of the fuels. The challenge, however, is that the solid fuels will be mixed into the cement raw materials, which is likely to affect process stability and clinker quality, as described above.

The mixing of fuels and raw materials was studied experimentally in a pilot-scale rotary drum and was found to be a fast process, reaching steady state within few drum revolutions. Thus, heat transfer by conduction from the cement raw materials to the fuel particles is a major heat transfer mechanism rather than convection or radiation from the freeboard gas above the material bed.

Consequently, the temperature of the cement raw materials becomes a factor of great importance for heating the fuel particles. Combustion of different alternative fuels has been investigated experimentally in a pilot-scale rotary furnace under conditions similar to those in the material inlet end of cement rotary kilns. The main focus was on tire rubber and
Combustion of solid alternative fuels in the cement kiln burner

In the cement industry there is an increasing environmental and financial motivation for substituting conventional fossil fuels with alternative fuels, being biomass or waste derived fuels. However, the introduction of alternative fuels may influence emissions, cement product quality, process stability, and process efficiency. Alternative fuel substitution in the calciner unit has reached close to 100% at many cement plants and to further increase the use of alternative fuels rotary kiln substitution must be enhanced. At present, limited systematic knowledge of the alternative fuel combustion properties and the influence on the flame formation is available. In this project a scientific approach to increase the fundamental understanding of alternative fuel conversion in the rotary kiln burner is employed through literature studies, experimental combustion characterisation studies, combustion modelling, data collection and observations at an industrial cement plant firing alternative fuels.

Alternative fuels may differ from conventional fossil fuels in combustion behaviour through differences in physical and chemical properties and reaction kinetics. Often solid alternative fuels are available at significant larger particle sizes than solid fossil fuels due to the cost of downsizing. Through theoretical evaluation it is found that the devolatilisation of large fuel particles is mainly limited by internal heat transfer and the char oxidation is dominated by external $O_2$ diffusion at conditions relevant to suspension fired combustion.

An experimental combustion reactor for simulating suspension fired combustion of large, single particles is established and experiments are performed to investigate conversion pathways, ignition, devolatilisation, and char oxidation times of pine wood, and three types of dried sewage sludge as function of particle size and shape, $O_2$ concentration, and gas temperature. Results show that the main factors affecting the time of devolatilisation is the gas temperature and particle size and shape. Factors affecting char oxidation rates include gas temperature, $O_2$ concentration, and particle size and shape.

A one-dimensional mathematical model of the rotary kiln flame is developed to evaluate the influence of fuel properties and combustion system parameters on the fuel burnout and flame temperature profile. Two alternative fuel cases are simulated; dried sewage sludge and refuse derived fuel firing. Firing sewage sludge or refused derived fuel with large particles and high moisture contents at conditions similar to a coal fired flame results in an elongated flame and a burnout time exceeding the available time in suspension. Fuel pretreatment, i.e. grinding and drying, is insufficient to ensure the dried sewage sludge to be converted within the available time in suspension, however a partial particle downsizing without drying can be allowed for refuse derived fuel firing. By increasing the entrainment rate of secondary air, the primary air percentage, the excess air ratio and applying $O_2$ enrichment it is found that full conversion of the large alternative fuel...
particles may be reached. The simplified mathematical model may serve as a tool for predicting the effect of introducing new fuels on burnout behaviour, and flame properties such as flame length and gas temperature profile in a rotary kiln flame.

**General information**

State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Number of pages: 162
Publication date: 2012

**Publication information**

Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark (DTU)
Original language: English
Electronic versions:

PhD._thesis_Linda_N_rskov_31072012..PDF
Research output: Research › Ph.D. thesis – Annual report year: 2012

**Design and operation of a filter reactor for continuous production of a selected pharmaceutical intermediate**

A novel filter reactor system for continuous production of selected pharmaceutical intermediates is presented and experimentally verified. The filter reactor system consists of a mixed flow reactor equipped with a bottom filter, to retain solid reactant particles, followed by a conventional plug flow reactor, where residual reactant is converted by titration. A chemical case study, production of the pharmaceutical intermediate allylcarbinol by a reaction between allylmagnesium chloride and 2-chloro-thioxanthone, in the presence of a side reaction is considered. The synthesis is conducted in tetrahydrofuran solvent. The use of the filter reactor design was explored by examining the transferability of a synthesis step in a present full-scale semi-batch pharmaceutical production into continuous processing. The main advantages of the new continuous minireactor system, compared to the conventional semi-batch operation, are reduced impurity formation and the use of much lower reactor volumes (factor of 1000 based on the laboratory reactor) and less solvent consumption (from 5.8 to 2.3L/kg reactant). Added challenges include handling of continuous solid powder feeding, stable pumping of reactive slurries, and a possibility of continuous control.

**General information**

State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, H. Lundbeck A/S, Technical University of Denmark
Contributors: Christensen, K. M., Pedersen, M. J., Dam-Johansen, K., Holm, T. L., Skovby, T., Kiil, S.
Pages: 111-117
Publication date: 2012
Peer-reviewed: Yes

**Publication information**

Journal: Chemical Engineering Science
Volume: 71
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.06
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
Web of Science (2016): Impact factor 2.895
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
Web of Science (2015): Impact factor 2.75
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.81 SJR 1.104 SNIP 1.629
Web of Science (2014): Impact factor 2.337
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.95 SJR 1.145 SNIP 1.843
Web of Science (2013): Impact factor 2.613
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.77 SJR 1.172 SNIP 1.828
Web of Science (2012): Impact factor 2.386
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 2.8 SJR 1.19 SNIP 1.678
Web of Science (2011): Impact factor 2.431
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.312 SNIP 1.698
Web of Science (2010): Impact factor 2.379
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.289 SNIP 1.742
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.294 SNIP 1.584
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.332 SNIP 1.553
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.305 SNIP 1.563
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.44 SNIP 1.775
Scopus rating (2004): SJR 1.299 SNIP 1.844
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.697 SNIP 1.661
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.864 SNIP 1.286
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 1.66 SNIP 1.732
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 1.124 SNIP 1.308
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 1.178 SNIP 1.511

Original language: English
Keywords: Continuous design, Chemical reactors, Batch, Pharmaceuticals, Grignard, Optimization
Source: orbit
Source-ID: 318426
Research output: Research - peer-review > Journal article – Annual report year: 2012
Devolatilization and Combustion of Tire Rubber and Pine Wood in a Pilot Scale Rotary Kiln

Cement production is highly energy intensive and requires large quantities of fuels. For both economical and environmental reasons, there is an increasing tendency for utilization of alternative fuels in the cement industry, examples being tire derived fuels, waste wood, or different types of industrial waste. In this study, devolatilization and combustion of large particles of tire rubber and pine wood with equivalent diameters of 10 mm to 26 mm are investigated in a pilot scale rotary kiln able to simulate the process conditions present in the material inlet end of cement rotary kilns. Investigated temperatures varied from 700 to 1000 °C, and oxygen concentrations varied from 5% v/v O₂ to 21% v/v O₂. The devolatilization time of tire rubber and pine wood were found to mainly depend on temperature and particle size and were within 40 to 170 s. Rate limiting parameters for char oxidation of tire rubber and pine wood were found to be bulk oxygen concentration, mass transfer rate of oxygen, raw material fill degree, raw material characteristics, and temperature. Kiln rotational speed only had a minor effect on the char oxidation when the raw material bed was in a rolling motion. Initial fuel particle size also influenced the char conversion time for pine wood char but had no influence on tire char conversion time, because the tire rubber cracked into several smaller char fragments immediately after devolatilization. The char conversion times were from 40 to 480 s for tire char and from 30 to 1300 s for pine wood char, depending on the conditions. Models for devolatilization and char oxidation of tire rubber and pine wood are validated against experimental results.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Pages: 854-868
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 26
Issue number: 2
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Impact factor 2.79
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.52
Web of Science (2013): Impact factor 2.733
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.25
Flash pyrolysis properties of algae and lignin residue

A fast pyrolysis study on lignin and macroalgae (non-conventional biomass) and wood and straw (conventional biomass) were carried out in a pyrolysis centrifugal reactor. The product distributions and energy recoveries were measured and compared among these biomasses. The fast pyrolysis of macroalgae showed a promising result with an yield of 54 wt% dry ash free basis (daf) and 78% energy recovery in the bio-oil. The physiochemical properties of the bio-oils were characterized with respect to higher heating value, molecular mass.
distribution, viscosity, pH, density and elemental compositions. The lignin and macroalgae oil properties were quite different to those of the conventional oils.

**General information**
**State:** Published
**Organisations:** Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Danish Polymer Centre, DONG Energy AS
**Contributors:** Trinh, N. T., Jensen, P. A., Sørensen, H. R., Dam-Johansen, K., Hvilsted, S.
**Publication date:** 2012
**Peer-reviewed:** Yes
**Event:** Abstract from European Biomass Conference and Exhibition, Milan, Italy.
**Keywords:** Fast pyrolysis, Lignin, Macroalgae, Wood, Straw, Bio-oil properties
**Electronic versions:**

**Flash Pyrolysis Properties Of Algae And Lignin Residue**
**Source:** dtu
**Source-ID:** u::4606
**Research output:** Research - peer-review » Conference abstract for conference – Annual report year: 2012

**Fuldskala kontinuerligt farmaceutisk produktion i minireaktorer**

**General information**
**State:** Published
**Organisations:** Department of Chemical and Biochemical Engineering, CHEC Research Centre, H. Lundbeck A/S
**Contributors:** Pedersen, M. J., Lønberg Holm, T., Pram Nielsen, J., Skovby, T., Mealy, M. J., Dam-Johansen, K., Kiil, S.
**Pages:** 8-10
**Publication date:** 2012
**Peer-reviewed:** Unknown
**Publication information**
**Journal:** Dansk Kemi
**Volume:** 93
**Issue number:** 6/7
**ISSN (Print):** 0011-6335
**Ratings:**
- ISI indexed (2013): ISI indexed no
- ISI indexed (2012): ISI indexed no
- ISI indexed (2011): ISI indexed no
- Web of Science (2007): Indexed yes
- Web of Science (2004): Indexed yes
**Original language:** Danish
**URLs:**
http://techmedia.swiflet.com/tm/dak/54/1/
**Research output:** Communication » Journal article – Annual report year: 2012

**Intumescent coatings under fast heating**
Intumescent coatings are widely used to delay or minimise the destructive effects of fire. They are usually tested under conditions that simulate the relatively slow build-up of heat in a normal fire. Here, the effects of damage during a fire causing sudden heating of the coating were studied.

**General information**
**State:** Published
**Organisations:** Department of Chemical and Biochemical Engineering, CHEC Research Centre
**Contributors:** Nørgaard, K. P., Dam-Johansen, K., Català, P., Kiil, S.
**Pages:** 34-39
**Publication date:** 2012
**Peer-reviewed:** No
**Publication information**
**Journal:** European Coatings Journal
**Volume:** 6
**ISSN (Print):** 0930-3847
Intumescent coatings under fast heating

Intumescent coatings are widely used in construction because they can delay fire and reduce damage caused by fire. Usually, the effectiveness of such coatings is simulated under slow temperature conditions, as in a normal fire. In our study, the consequences of fast heating were considered.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Nørgaard, K. P., Dam-Johansen, K., Catala, P., Kiil, S.
Pages: 17-20
Publication date: 2012
Peer-reviewed: Yes
Methane steam reforming kinetics over Ni-YSZ anodematerials for Solid Oxide Fuel Cells

Solid Oxide Fuel Cells (SOFC) is a technology with great potential. Its high efficiency makes it a relevant alternative to existing technologies for utilizing fossil fuels and its fuel versatility makes it invaluable in the transition from a fossil fuel based energy system to one based on renewable energy.

The overall efficiency of a fuel cell system operating on natural gas can be significantly improved by having part of the steam reforming take place inside the SOFC stack. In order to avoid large temperature gradients as a result of the highly endothermal steam reforming reaction, the amount of internal reforming has to be carefully controlled. The objective of this thesis is to make such a careful control possible by examining the rate of internal steam reforming in SOFCs.

The catalytic steam reforming activity of Ni-YSZ anode material was tested both in a packed bed reactor to determine intrinsic kinetics, and in a stack configuration to determine the rate observed under realistic SOFC conditions. The kinetic expressions obtained from respectively the packed bed measurements and the stack measurements are shown in Equations 3 and 4.

Furthermore, a simple model was derived, which can accurately predict the steam reforming rate in a stack from the rate expression obtained from the packed bed experiments.

During the experiments a previously unreported long term dynamic behavior of the catalyst was observed. After startup, the initial high reactivity was slowly reduced by a factor 5-10 over a period of several days or several weeks depending on operating temperature. It was also found that prolonged exposure to a H₂O/H₂ mixture without CH₄ resulted in a reactivation of the catalytic activity up to the initial high level. It was attempted to account for this behavior through characterization with SEM, TEM, XRD and EXAFS.

Microcapsule-based self-healing anticorrosive coatings: Capsule size, coating formulation, and exposure testing

Self-healing coatings is a rapidly growing research area, where focus has mainly been on development of new approaches to the mechanism of self-healing. However, there is a growing need for investigation of practical issues related to formulation, application, and testing of true self-healing coatings. In this work, ways of reducing the size of
poly(urea–formaldehyde) microcapsules, filled with linseed oil and intended for a microcapsule-based self-healing anticorrosive coating (above water exposure), are explored. The influence of microcapsules on epoxy coating performance is also studied. The actual self-healing effect was not part of this work. The synthesis parameters investigated are stirrer geometry, agitation rate, temperature, and stabilizer concentration. It was found that an increase in stirring rate, correct choice of temperature, and a high stabilizer concentration all caused a decrease in microcapsule size but were accompanied by excessive formation of nanoparticles. Thus, isolation of too large microcapsules has been performed by filtration utilizing a novel low-energy fluoropolymer-coated steel sieve. An estimation of the critical pigment (microcapsule) volume concentration (CPVC) was conducted using gloss measurements and a PVC ladder and found to be about 30 vol%. Due to the rather large capsules used (relative to the coating thickness), the low CPVC value can probably be ascribed to a fairly low packing efficiency in the coating, but this needs to be confirmed. Coating performance was evaluated using salt spray exposure and impact testing. Results of the impact testing showed that addition of microcapsules to a binder matrix did not compromise resistance of the coating to mechanical damage and led to formation of fewer and shorter cracks compared to a filler-containing coating. Flaking of the coating was also reduced. Results of the salt spray testing (3 weeks exposure) showed that with an increase of microcapsule content, in the interval 30–50 vol%, the extent of corrosion and potential coating delamination decreased and was identical to that of a full commercial anticorrosive coating.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Hempel A/S
Contributors: Nesterova, T., Dam-Johansen, K., Pedersen, L. T., Kiil, S.
Pages: 309-318
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: Progress in Organic Coatings
Volume: 75
Issue number: 4
ISSN (Print): 0300-9440
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): SJR 0.844 SNIP 1.288
Web of Science (2017): Impact factor 2.955
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.89 SJR 0.852 SNIP 1.335
Web of Science (2016): Impact factor 2.858
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.84 SJR 0.857 SNIP 1.384
Web of Science (2015): Impact factor 2.632
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.8 SJR 0.997 SNIP 1.585
Web of Science (2014): Impact factor 2.358
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.58 SJR 1.03 SNIP 1.642
Web of Science (2013): Impact factor 2.302
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.39 SJR 1.048 SNIP 1.83
Web of Science (2012): Impact factor 1.848
ISI indexed (2012): ISI indexed yes
Monitoring and Control of a Continuous Grignard Reaction for the Synthesis of an Active Pharmaceutical Ingredient Intermediate Using Inline NIR spectroscopy

Inline near-infrared (NIR) spectroscopy has been used to monitor a continuous synthesis of an active pharmaceutical ingredient (API) intermediate by a Grignard alkylation reaction. The reaction between a ketone substrate and allylmagnesium chloride may form significant impurities with excess feeding of the Grignard reagent beyond the stoichiometric ratio. On the other hand, limiting this reagent would imply a loss in yield. Therefore, accurate dosing of the two reactants is essential. A feedforward–feedback control loop was conceived in order to maintain the reaction as closely as possible to the stoichiometric ratio, leading the path to full process automation. The feedback control loop relies on NIR transmission measurements performed in a flow cell where, in contrast to labor-intensive offline HPLC analytical methods, the whole reaction product can be scanned in real time without sample dilution. A robust PLS (projection to latent structures) model was developed with a satisfactory standard error of prediction, providing quantification of the ketone substrate in solutions with a high variability of the major solution component - the alkoxide product. In addition, model performance supervision tools such as the spectral residuals or simple plots of pretreated spectra can assist in the identification of spectral outliers, which in this case could be related to Grignard reagent excess. If the sampling time of the NIR instrument is short enough, manipulating the inputs to the reactor may be used to obtain information about its dynamic behavior. This information is very useful for process control design, assessment of analytical tools and definition of sampling times. In this work, a systematic procedure for chemometric model building is followed, after which a discussion is made on some of the potential applications that can be found when exploiting the fast and rich information provided by NIR spectroscopy.
Self-Healing anticorrosive coatings

Self-healing anticorrosive coatings are multi-component so-called smart materials, which have been proposed as a way to long-lasting corrosion protection of steel structures. The presently most promising technology route is based on microcapsules, filled with active healing agents, and has been the focus of this work. The microcapsules consist of a solid polymeric shell and a liquid core material. When a microcrack, originating from internal stress or a physical damage, propagates through the coating, the microcapsules rupture and release healing agents, which flow to the fracture plane due to capillary forces. The healing agents then start to react, form a polymer network, and ‘glue’ the crack. The approach has been applied to development of an epoxy-based self-healing anticorrosive coating for above water heavy duty corrosion protection. Emphasis has been on investigation of practical issues associated with development and testing of this type of coating.

A laboratory investigation, to identify the most suitable method for production of mechanically stable (filled with industrially relevant core materials) and forming a free-flowing powder upon drying microcapsules, has been performed. Four different experimental procedures, available in the literature, have been used for encapsulation of six core materials, including epoxy resins, diluent, and linseed oil. Several challenges have been identified during the investigations. Main of them dealt with encapsulation of viscous healing agents and a necessity of a thorough adjustment of the synthesis procedures for a wider use with other than original core materials. Free-flowing powders of two types of microcapsules (filled with linseed oil and alkylglycidylether) have been produced and investigated for solvent stability, stability towards stirring and storage, as well as ease of capsule dispersion. A systematic laboratory study, for reduction of poly(urea-formaldehyde) microcapsule size, filled with linseed oil, has been performed. Several synthesis parameters were varied (temperature, stabilizer content, stirring rate, stirrer geometry) and mechanical means of separation were investigated. Capsules with a mean diameter less than 150 µm were obtained using a steel sieve coated with a fluoropolymer coating. These smaller capsules were used in further investigation as model capsules.

A range of microcapsule-containing coatings was formulated, applied to steel substrates, and subjected to salt spray exposure and reverse impact testing. Neither of the tests revealed any drawbacks from addition of microcapsules to an epoxy coating in a concentration up to 50 vol %. On the contrary, the results of the impact test has shown that addition of microcapsules reduces the intensity of crack formation (both in number and length) compared to filler-containing coatings and prevents the coating from flaking upon damage. Based on specular gloss measurements, a preliminary critical pigment (microcapsule) concentration (CPVC) value was estimated to about 30 vol %. The number is lower than anticipated and needs to be confirmed.

Finally, a 3-D model, based on Monte-Carlo simulations, has been developed for prediction of healing efficiency of a microcapsule-based anticorrosive coating. Two kinds of cracks were considered: cracks accommodated within the bulk
coating and cracks starting from the coating surface. The model takes into account volume of the crack formed, crack
gamma and linear dimensions, as well as diameter, volume concentration, and wall thickness of the microcapsules
embedded in the coating. Simulations showed that diameter of microcapsules and crack geometry played an important
role in the self-healing action of the coating, especially when low concentrations of capsules were used.

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Hempel A/S
Contributors: Nesterova, T., Dam-Johansen, K., Pedersen, L. T., Kiil, S.
Number of pages: 130
Publication date: 2012

**Publication information**
Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark (DTU)
Original language: English
Electronic versions:
Dansk_Resume_af_PhD_afhandling_Tatyana_Nesterova..pdf
PhD_Thesis_Tatyana_Nesterova..PDF
Research output: Research › Ph.D. thesis – Annual report year: 2012

**Suspension-Firing of Biomass: Part 1, Full-Scale Measurements of Ash Deposit Build-up**
This paper is Part 1 in a series of two describing probe measurements of deposit build-up and removal (shedding) in a 350
MWth suspension boiler, firing straw and wood. The influence of fuel type (straw share in wood), probe exposure time,
probe surface temperature (500, 550, and 600 °C), and flue gas temperature (600–1050 °C) on ash deposit formation rate
has been investigated. Investigations of deposit formation rate were made by use of an advanced online deposit probe
that allowed nearly continuous measurement of the deposited mass. Two different measures of deposit formation rate are
used in the analysis of the data. The first is the integral deposit formation rate (IDF-rate) found by dividing the integral
mass change over integral time intervals (of order several hours) by the time interval. The IDF-rate is similar to deposit
formation rates based on total deposit mass uptake divided by probe exposure time reported in previous full-scale
investigations, but it is a relatively crude measure that includes all deposit shedding in addition to actual deposit formation.
To remove major shedding events from the determination of deposition rates a second measure, the derivative-based
deposit formation rate (DDF-rate), was devised. This was determined by averaging the deposit mass uptake signals over
short time intervals (on the order of minutes), calculating the local values of the time derivative of the mass uptake,
removing large negative values signifying major shedding events, and finally time smoothing the derivatives to remove
excessive noise. The DDF-rate was influenced by flue gas temperature and straw share, while changes in probe surface
temperature had no significant influence. The IDF-rate, qualitatively related to the ratio between the time-integrated DDF-
rate and the integration time, followed the same trends. Ash transformation was investigated by bulk ash analysis of the
fuel, fly, and bottom ash during straw and/or wood suspension firing. Bulk ash analysis of fly ashes showed that the
contents of volatile elements (K, Cl, S) were slightly greater than in the fuel ash, while Ca and Si remained either in the
same proportion or were slightly reduced. It was also found that, with an increase in fuel ash K/Si molar ratio, the
concentration of the volatile elements, K, Cl, and, to some extent, S, increased in the fly ash. The bottom ash was
dominated by Si and Ca, with almost no S and Cl, possibly as a result of the high volatility of S and Cl during combustion
at higher temperatures.

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Vattenfall Vindkraft A/S
Pages: 2317-2330
Publication date: 2012
Peer-reviewed: Yes

**Publication information**
Journal: Energy & Fuels
Volume: 26
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Suspension-Firing of Biomass: Part 2, Boiler Measurements of Ash Deposit Shedding

This paper is the second of two papers, describing probe measurements of deposit buildup and removal (shedding), conducted in a 350 MWth suspension-fired boiler, firing straw and wood. Investigations of deposit buildup and shedding have been made by use of an advanced online deposit probe and a sootblowing probe. The influences of feedstock (i.e., straw share in wood), flue gas temperature (600−1050 °C), probe surface temperature (500 and 600 °C), and probe exposure time on deposit shedding have been quantified. Quantification of naturally occurring deposit shedding and deposit shedding during plant sootblowing was made via deposit mass uptake signals obtained from the deposit probe. The deposit shedding process was characterized by calculation of the amount of deposit removed at a shedding event (g/m²2) and the frequency of the shedding events (h−1). The results showed that the shedding process is stochastic and that the amount of deposit shed varies even at constant local conditions. However, the deposit shedding rates showed an increasing trend with increase in flue gas temperatures and probe deposit mass loads. The deposit shedding rate was in most cases higher at a probe temperature of 500 °C than at a probe temperature of 600 °C. A possible reason for this is partial melting and/or sintering of the innermost deposit layer (rich in K, Cl, and S) at higher probe surface temperature. This could cause the adhesion strength of the deposit to the probe to increase at the higher probe temperature.

Quantification of the necessary peak impact pressure (PIP) needed to remove the deposit was also made by use of a sootblowing probe in conjunction with the deposit probe. Results of deposit removal by artificial sootblowing showed that the deposits formed on a 500 °C probe temperature and at exposure times of <91 h can be removed with a PIP of <55 kPa. However, increase in probe exposure time and/or probe surface temperature (600 °C) significantly increases the PIP needed to remove the deposits.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Vattenfall
Pages: 5241-5255
Publication date: 2012
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 26
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Impact factor 2.79
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.52
Web of Science (2013): Impact factor 2.733
Suspension-firing of wood with coal ash addition: Probe measurements of ash deposit build-up at Avedøre Power Plant (AVV2)

This report is about full-scale probe measurements of deposit build-up and removal conducted at the Avedøreværket Unit 2, a 800 MWth suspension boiler, firing wood and natural gas with the addition of coal ash. Coal ash was used as an additive to capture potassium (K) from wood-firing. Investigations of deposit formation rate were made by use of an advanced online ash deposition/shedding probe. Quantification of ash deposition and shedding was made via deposit mass uptake signals obtained from the deposit probe. The influence of coal ash, flue gas temperature, probe surface temperature and boiler load on ash deposition propensity was investigated. Results of ash deposition propensity showed increasing trend with increasing flue gas temperature. Video monitoring revealed that the deposits formed were not sticky and could be easily removed, and even at very high flue gas temperatures (> 1350 oC), deposit removal through surface melting was not identified. SEM-EDS analysis of the deposits showed significant presence of Ca, Al and Si, indicating that a significant amount of K has been captured by coal ash to form deposits rich in calcium-aluminum-silicates, and possible release of Cl to the gas phase as HCl(g). Effect of boiler operational parameters on gas emissions has also been investigated.

General information
State: Published
A method and a mobile unit for collecting and pyrolysing biomass

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Bech, N., Dam-Johansen, K.
Publication date: 2011

Publication information
IPC: A01D43/00
Patent number: AU 2006243569
Date: 19/05/2011
Original language: English
Source: orbit
Source-ID: 317014
Research output: Research › Patent – Annual report year: 2011

A Model for Nitrogen Chemistry in Oxy-Fuel Combustion of Pulverized Coal
In this work, a model for the nitrogen chemistry in the oxy-fuel combustion of pulverized coal has been developed. The model is a chemical reaction engineering type of model with a detailed reaction mechanism for the gas-phase chemistry, together with a simplified description of the mixing of flows, heating and devolatilization of particles, and gas–solid reactions. The model is validated by comparison with entrained flow reactor results from the present work and from the literature on pulverized coal combustion in O2/CO2 and air, covering the effects of fuel, mixing conditions, temperature, stoichiometry, and inlet NO level. In general, the model provides a satisfactory description of NO formation in air and oxy-fuel combustion of coal, but under some conditions, it underestimates the impact on NO of replacing N2 with CO2. According to the model, differences in the NO yield between the oxy-fuel combustion and the conventional combustion of pulverized coal can mostly be attributed to the recycling of NO (reburning effect) and to changes in the mixing patterns between fuel and oxygen. For pulverized-fuel combustion at high temperatures, we think that NO is mainly reduced by heterogeneous reactions involving both char and soot. Here, the tar yield of the volatiles is mainly converted to soot and H2, limiting the concentration of hydrocarbons and thereby the importance of gas-phase removal of NO. Our work emphasizes the need for accurate descriptions of mixing, volatile composition (fate of tar), and heterogeneous reactions. Furthermore, more work is desirable on the reduction of NO by CO on char at higher temperatures.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Hashemi, H., Hansen, S., Toftegaard, M. B., Pedersen, K. H., Jensen, A. D., Dam-Johansen, K., Glarborg, P.
Pages: 4280-4289
Publication date: 2011
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 25
Issue number: 10
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Carbonate Looping for De-Carbonization of Cement Plants
Cement industry is one of the largest emitters of CO2 other than power generation plants, which includes the emissions from combustion of fuel and also from calcination of limestone for clinker production. In order to reduce CO2 emissions from the cement industry an effective and economically feasible technology is to be developed. The carbonate looping process is a promising technology, which is particularly suitable for the cement industry as limestone could be used for capture and release of CO2. Integration of carbonate looping process into cement pyroprocess has two advantages: 1) to capture emitted CO2 and 2) to generate power for internal use, because high quality energy can be recovered from carbonate looping which is operated at high temperature unlike amine process. A simple carbonate looping process model was developed based on average conversion of calcined limestone defined by Abanades et al. The model is used to investigate the influence of average conversion of limestone in the carbonator on the flow rates of different streams in the looping process and energy required in the calciner for re-activation. The model developed is used for studying the carbonate looping process integrated into cement pyro-process. The energy required for regeneration in the calciner increases with increase in average conversion of calcined limestone and energy that can be extracted from carbonator decreases with increasing average conversion. Further the influence of type of limestone on the calciner capacity is also investigated. The results from this simple model show the importance of cement industry to the carbon capture technology for its application to power plants.

Co-combustion of Fossil Fuels and Waste
The Ph.D. thesis deals with the alternative and high efficiency methods of using waste-derived fuels in heat and power production. The focus is on the following subjects: 1) co-combustion of coal and solid recovered fuel (SRF) under pulverized fuel combustion conditions; 2) dust-firing of straw and the utilization of a waste-derived material as an additive; 3) the combustion of a biomass residue rich in phosphorus. Co-combustion of coal and SRF was conducted in an entrained flow reactor (EFR). The work revealed that when coal was co-fired with up to 25 wt% SRF, the burnout and the emissions of SO2 and NO were decreased with increasing share of SRF, probably due to the combustion characteristics of the SRF and/or the interactions between the SRF and the coal in co-combustion. The Cl content in the fly ash was very low.
Co-combustion of pulverized coal and solid recovered fuel in an entrained flow reactor- General combustion and ash behavior

Co-combustion of a bituminous coal and a solid recovered fuel (SRF) was carried out in an entrained flow reactor, and the influence of additives such as NaCl, PVC, ammonium sulphate, and kaolinite on co-combustion was investigated. The co-combustion experiments were carried out with SRF shares of 7.9 wt.%, 14.8 wt.% and 25 wt.%, respectively. The effect of additives was evaluated by maintaining the share of secondary fuel (mixture of SRF and additive) at 14.8 wt.%. The experimental results showed that the fuel burnout, NO and SO2 emission in co-combustion of coal and SRF were decreased with increasing share of SRF. The majority of the additives inhibited the burnout, except for NaCl which seemed to have a promoting effect. The impact of additives on NO emission was mostly insignificant, except for ammonium sulphate which greatly reduced the NO emission. For SO2 emission, it was found that all of the additives increased the S-retention in ash. Analysis of the bulk composition of fly ash from different experiments indicated that the majority of S and Cl in the fuels were released to gas phase during combustion, whereas the K and Na in the fuels were mainly retained in ash. When co-firing coal and SRF, approximately 99 wt.% of the K and Na in fly ash was present in water insoluble form such as aluminosilicates or silicates. The addition of NaCl, PVC, and ammonium sulphate generally promoted the vaporization of Na and K, resulting in an increased formation of water soluble alkalis such as alkali chlorides or sulphates. The vaporization degree of Na and K was found to be correlated during the experiments, suggesting an interaction between the vaporization of Na and K during pulverized fuel combustion. By collecting deposits on an air-cooled probe during the experiments, it was found that the ash deposition propensity in co-combustion was decreased with increasing share of SRF. The addition of NaCl and PVC significantly increased the ash deposition propensity, whereas the addition of ammonium sulphate or kaolinite showed a slight reducing effect. The chlorine content in the deposits generally implied a low corrosion potential during co-combustion of coal and SRF, except for the experiments with NaCl or PVC addition.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, DONG Energy AS
Publication date: 2011
Peer-reviewed: Yes

Publication information
Journal: Fuel
Volume: 90
Issue number: 5
ISSN (Print): 0016-2361
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.4 SJR 1.891 SNIP 2.127
Web of Science (2017): Impact factor 4.908
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.9 SJR 1.736 SNIP 2.207
Web of Science (2016): Impact factor 4.601
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.46 SJR 1.781 SNIP 2.123
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 4.14 SJR 1.634 SNIP 2.294
Web of Science (2014): Impact factor 3.52
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Dust-Firing of Straw and Additives: Ash Chemistry and Deposition Behavior

In the present work, the ash chemistry and deposition behavior during straw dust-firing were studied by performing experiments in an entrained flow reactor. The effect of using spent bleaching earth (SBE) as an additive in straw combustion was also investigated by comparing with kaolinite. During dust-firing of straw, the large (>∼2.5 μm) fly ash particles generated were primarily molten or partially molten spherical particles rich in K, Si, and Ca, supplemented by Si-rich flake-shaped particles. The smaller fly ash particles...
Formation of fine particles in co-combustion of coal and solid recovered fuel in a pulverized coal-fired power station

Fine particles formed from combustion of a bituminous coal and co-combustion of coal with 7 th% (thermal percentage) solid recovered fuel (SRF) in a pulverized coal-fired power plant were sampled and characterized in this study. The particles from dedicated coal combustion and co-combustion both showed an ultrafine mode centered at approximately 0.1 μm. Compared with coal combustion, co-combustion of coal and SRF increased the formation of submicron particles, especially ultrafine particles below 0.2 μm. The morphology of the particles indicated that supermicron particles were primarily formed by the melting of minerals. The ultrafine particles were generated through nucleation and coagulation of vaporized inorganic species, while for the particles in between supermicron and ultrafine particles, condensation of vaporized species or aggregation of nucleates on the existing spherical submicron particles appear to be an important formation mechanism. The elemental composition of the particles from coal combustion showed that S and Ca were significantly enriched in ultrafine particles and P was also enriched considerably. However, compared with supermicron particles, the contents of Al, Si and K were depleted in ultrafine particles. The observed high volatility of Ca was likely related with the high combustion temperature and relative low oxygen condition in the boiler which may promote vaporization of Ca during char oxidation. The discrepancies on the observed volatilities of Ca and alkalis between some laboratory experiments and full-scale measurements were discussed. The composition of the fine particles from co-combustion was generally similar to those from coal combustion. The ultrafine particles from co-combustion were of slightly higher Ca, P, and K contents, and lower S content.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, DONG Energy AS
Contributors: Wu, H., Pedersen, A. J., Glarborg, P., Frandsen, F., Dam-Johansen, K., Sander, B.
Pages: 2845-2852
Publication date: 2011
Peer-reviewed: Yes

Publication information
Journal: Proceedings of the Combustion Institute
High-Temperature Release of SO₂ from Calcined Cement Raw Materials

During combustion of alternative fuels in the material inlet end of cement rotary kilns, local reducing conditions may occur and cause reductive decomposition of sulfates from calcined cement raw materials. Decomposition of sulfates is problematic because it increases the gas-phase SO₂ concentration, which may cause deposit formation in the kiln system. In this study, the release of sulfur from calcined cement raw materials under both oxidizing and reducing conditions is investigated. The investigations include thermodynamic equilibrium calculations in the temperature interval of 800–1500 °C and experiments in a tube furnace reactor in the temperature interval of 900–1100 °C. The investigated conditions resemble actual conditions in the material inlet end of cement rotary kilns. It was found that the sulfates CaSO₄, K₂SO₄, and Na₂SO₄ were all stable under oxidizing conditions but began to decompose under reducing conditions. Particularly, CaSO₄ was sensitive to reducing conditions. The sulfur release was most significant if the gas atmosphere frequently shifted between oxidizing and reducing conditions. An increasing temperature from 900 to 1100 °C under alternating oxidizing and reducing conditions was also observed to increase the sulfur release from the calcined raw materials by a factor of 3, from 14 to 48%.
Influence of fast pyrolysis temperature on biochar labile fraction and short-term carbon loss in a loamy soil

Production of bio-oil, gas and biochar from pyrolysis of biomass is considered a promising technology for combined production of bioenergy and recalcitrant carbon (C) suitable for sequestration in soil. Using a fast pyrolysis centrifuge reactor (PCR) the present study investigated the relation between fast pyrolysis of wheat straw at different reactor temperatures and the short-term degradability of biochar in soil. After 115 days incubation 3–12% of the added biochar-C had been emitted as CO2. On average, 90% of the total biochar-C loss occurred within the first 20 days of the experiment, emphasizing the importance of knowing the biochar labile fraction when evaluating a specific biochars C sequestration potential. The pyrolysis temperature influenced the outputs of biochar, bio-oil and syngas significantly, as well as the stability of the biochar produced. Contrary to slow pyrolysis a fast pyrolysis process may result in incomplete conversion of biomass due to limitations to heat transfer and kinetics. In our case chemical analysis of the biochars revealed unconverted cellulosic and hemicellulosic fractions, which in turn were found to be proportional with the short-term biochar degradation in soil. As these labile carbohydrates are rapidly mineralized, their presence lowers the biochar-C sequestration potential. By raising the pyrolysis temperature, biochar with none or low contents of these fractions can be produced, but this will be on the expense of the biochar quantity. The yield of CO2 neutral bio-oil is the other factor to optimize when adjusting the pyrolysis temperature settings to give the overall greatest climate change mitigation effect.

General information
State: Published
Organisations: Risø National Laboratory for Sustainable Energy, Ecosystems, Biosystems Division, CHEC Research Centre, Department of Chemical and Biochemical Engineering, Biomass Gasification
Pages: 1182-1189
Publication date: 2011
Peer-reviewed: Yes

Publication information
Journal: Biomass & Bioenergy
Volume: 35
Issue number: 3
ISSN (Print): 0961-9534
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4 SJR 1.235 SNIP 1.436
Web of Science (2017): Impact factor 3.358
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.71 SJR 1.198 SNIP 1.385
Web of Science (2016): Impact factor 3.219
Web of Science (2016): Indexed yes
Internal steam reforming in solid oxide fuel cells: Status and opportunities of kinetic studies and their impact on modelling

Solid oxide fuel cells (SOFC) systems with internal steam reforming have the potential to become an economically competitive technology for cogeneration power plants, exploiting its significantly higher electrical efficiency compared to existing technologies. Optimal design and operation of such a system require SOFC models that include accurate description of the steam reforming rate. The objective of this article is to review the reported kinetic expressions for the steam reforming reaction. Extensive work has been performed on traditional catalysts for steam reforming. Because of differences in operating conditions, catalyst support material and structure it is critical to transfer this knowledge directly to internal reforming in SOFCs, which is discussed in further detail in this article. There are big differences in the reported kinetic expression for steam reforming over both industrial Ni catalysts and SOFC anode materials. Surprisingly, there is a good agreement between measured rates pr. geometric anode area at high operating temperatures, even for very different anodes. Detailed experimental data on the intrinsic steam reforming kinetics of Ni-YSZ are necessary for micro structure SOFC modeling, such expression are however lacking, but it may be viable to use measurements on industrial steam reforming catalysts instead. Nevertheless there is a further need for experimental studies on determining the exact steam reforming kinetics for SOFC anodes.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Electroceramics, Fuel Cells and Solid State Chemistry Division, Rise National Laboratory for Sustainable Energy, Karlsruhe Institute of Technology, Haldor Topsoe AS
Contributors: Mogensen, D., Grunwaldt, J., Hendriksen, P. V., Dam-Johansen, K., Nielsen, J.
Pages: 25-38
Publication date: 2011
Peer-reviewed: Yes

Publication information
Journal: Journal of Power Sources
Volume: 196
Issue number: 1
ISSN (Print): 0378-7753
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 7 SJR 2.202 SNIP 1.536
Web of Science (2017): Impact factor 6.945
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 6.22 SJR 1.944 SNIP 1.5
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 6.34 SJR 1.9 SNIP 1.667
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 6.3 SJR 1.964 SNIP 2.042
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 5.63 SJR 1.975 SNIP 2.137
Web of Science (2013): Impact factor 5.211
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Kinetics of the direct sulfation of limestone at the initial stage of crystal growth of the solid product

The direct sulfation of limestone was studied in a quartz bench scale fixed-bed reactor with the technique of data deconvolution. The obtained results show that the direct sulfation of limestone has a two-period kinetic behavior: a short initial sulfation period with high but fast decreasing reaction rate and a subsequent period with product crystal growth with low-conversion rate. The transition from the first period to the second period is sharp and indicates clearly the start point of the period with product crystal growth. The transition point was determined by the concentrations of gases such as SO$_2$, O$_2$, and CO$_2$ and the temperature. The sulfation process in the initial stage of the period with product crystal growth can be described by the combination of the sulfation reaction at the gas–solid interface, diffusion of the product ions toward the product crystal grains, diffusion of carbonate ions toward the gas–solid interface to react, and the gradual shielding of calcite surface area by the product crystal grains. A simple and semi-empirical mathematical model derived on basis of this theory gives a satisfactory description of the experimental results up to a calcite conversion of about 0.5%. © 2010 American Institute of Chemical Engineers AIChE J, 2011
Low SO2 Emission Preheaters for Cement Production

The most common way of producing cement today is effected through what is known as the dry process. If the raw materials used in this process contain sulphide, the plant layout can lead to emissions of SO2 from the preheater tower. SO2 emissions are most often caused by the oxidation of pyritic sulphide, which occurs between 300 and 600 °C. Of the formed SO2, around 50% is often said to be emitted from the preheater. However, large variations in this number have been observed, with the circulation of CaO from the calciner given as the main reason for this phenomenon. One of the experimental goals in this thesis has been to produce CaO with a large surface area in order to increase the absorption of SO2. For this purpose flash calcination of CaCO3, calcination under vacuum, calcination in a fixed bed and a fluid bed has been tested between 650 °C and 850 °C. The results showed that flash calcination at low temperatures resulted in the largest surface area, about 140 m2/g CaO. The material produced from all of the methods was a mixture of CaO and CaCO3, meaning that the material was only partly calcined, but with the particle surface area being comprised by CaO.

One focus in this thesis was to investigate the reaction between CaO and SO2 in the temperature interval where SO2 is formed within the preheater tower, in order to understand the role of CaO in connection with SO2 emission. The experiments were conducted using CO2 concentrations up to 25 %. The reaction times in all cases were less than 1 second, which was possible using an entrained flow reactor. Furthermore, the experimental results were found to be limited by both external and internal diffusion. The reaction product was identified as a mixture of CaSO3 and CaSO4. For temperatures below 600 °C no effect from O2 was observed. At low CO2 concentrations the CaO conversion with respect to SO2 increased with both temperature and surface area. At high CO2 concentrations no effect or even a negative effect of temperature was seen. In general, CO2 was found to inhibit the CaO/SO2 reaction. Based on the CaO experiments under carbonating conditions it was concluded that CaO recirculation within the preheater tower does not influence the SO2 emission to any significant extent. This conclusion is opposite to what previously has been stated. Modelling of experimental results concentrates on the results obtained for CaO in non-CO2-enriched atmospheres. Due to external and internal diffusion limitations and very short reaction times, a time-dependent grain model with chemical reaction between SO2 and CaO at the shrinking core interface in the non-porous grains was used and found to describe data very well. The outcome of the modelling was that the chemical reaction between SO2 and CaO is so fast that the observed rates exclusively are determined by solid state diffusion in the product layer of the non-porous CaO grains. An activation energy of 115 kJ/mole was found to fit all CaO sources very well, even though data fitting by the least sum of squares method showed that this figure could be between 90 kJ/mole and 140 kJ/mole, with a corresponding change of preexponential factors. The ability to predict emissions is very important in the design of cement plants. In this thesis the zone model concept has been applied to the modelling of the cyclone stages in a preheater tower. The idea is to account for the complex flow pattern in a cyclone stage by dividing it into zones, each zone having special features. In this manner the model can account for gas/solid heat exchange, gas/solid separation, different gas and solid residence times, etc. The model was evaluated against SO2 data from five full-scale plants, showing satisfactory results in two cases. An investigation of the parameters showed that it was possible to obtain satisfactory results in four out of five cases by allowing the CaCO3 surface area available for SO2 absorption to be about 4 m2/g instead of the measured surface areas, which was up to around 10 m2/g.
Method and a Mobile Unit for Collecting Biomass

A method for collecting biomass, such as straw, and for producing a pyrolysis liquid, such as oil or tar, from the biomass, comprises the step of collecting the biomass from a growth site, e.g. a field, by means of a mobile unit. The biomass is continuously fed into a pyrolysis apparatus (200) accommodated by the mobile unit, as the mobile unit is moved across the growth site. While the biomass is processed in the pyrolysis apparatus, further biomass is simultaneously being collected. The pyrolysis apparatus may be a flash pyrolysis or fast pyrolysis apparatus relying on centrifugal forces for forcing biomass towards a reactive surface in a pyrolysis reactor. The mobile unit may be self-propelled.

Mixing large and small particles in a pilot scale rotary kiln

The mixing of solid alternative fuel particles in cement raw materials was studied experimentally by visual observation in a pilot scale rotary kiln. Fuel particles were placed on top of the raw material bed prior to the experiment. The percentage of particles visible above the bed as a function of time was evaluated with the bed predominantly in the rolling bed mode. Experiments were conducted to investigate the effects of fuel particle size and shape, fuel particle density, rotary kiln fill degree and rotational speed. Large fuel particles and low-density fuel particles appeared more on top of the bed than smaller particles and high-density fuel particles. Fuel particle dimensions and sphericity were important parameters for the percentage of visible particles. Increasing bed fill degree and/or increasing rotational speed decreased the percentage of particles visible on top of the bed. Results can be up-scaled to industrial conditions in cement rotary kilns and show that even relatively large fuel particles will predominantly be covered by raw material after less than 30s in the rotary kiln. This affects the heating and combustion mechanisms for the fuel particles.
Probe Measurements of Ash Deposit Formation Rate and Shedding in a Biomass Suspension-Fired boiler

The aim of this study was to investigate ash deposit formation rate, heat uptake reduction and deposit removal by using advanced online ash deposition and sootblowing probes in a 350 MWth suspension-fired boiler, utilizing wood and straw pellets as fuel. The influence of fuel type (straw share in wood), probe exposure time, probe surface temperature (500, 550 and 600 oC) and flue gas temperature (600 - 1050 oC) on ash deposition formation rate, heat uptake by the probe, the fly ash and deposit characteristics, and deposit removal have been investigated. The results indicated that increase in flue gas temperature increased the ash deposit formation rate. It was also found that probe heat uptake reduction was not strongly sensitive to the deposit mass load on the probe. This indicated that the heat transfer from the flue gas to the probe was dominated by the rear side, where little material was accumulated on the probe if the deposit mass load was very high on the flue gas facing side of the probe. Results of deposit removal by using sootblowing probe indicated that probe exposure time and surface temperature significantly influence the Peak Impact Pressure (PIP) needed to remove the deposits. The video recordings of all deposit probe experiments revealed that deposit shedding was primarily through debonding from the surface of the tubes in the superheater region. Chemical analysis of fly ashes indicated that during suspension-firing of straw and wood, the fly ashes were rich in Si, K, Ca and Cl, but the relative percentage of volatile elements (K, Cl and S) was much less compared to grate-firing conditions. The chemical analysis of the deposits showed that the inner most layer was dominated by contents of K, Cl and S compared to the upper layers rich in K, Si and Ca

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Vattenfall Vindkraft A/S
Number of pages: 14
Publication date: 2011
Peer-reviewed: Yes
Event: Abstract from 19th European Biomass Conference and Exhibition, Berlin, Germany.
Keywords: Biomass, Straw, Wood, Fly Ash, Fouling, Slaggin
Source: dtu
Source-ID: u::4630
Research output: Research - peer-review » Conference abstract for conference – Annual report year: 2012

PSO Project 10085: Final Report – Co-Firing of Coal and RDF in Suspension

Co-combustion of refuse derived fuels (RDF) with coal in pulverized coal-fired power plants can potentially increase the electrical efficiency of utilizing RDF and reduce the formation of some harmful pollutants such as dioxins. The objective of this project was to provide a general assessment of the technical issues related to co-combustion of coal and RDF, and to improve the fundamental understandings of this subject. The project was carried out in collaboration between the CHEC Research Centre at DTU Chemical Engineering and DONG Energy Power A/S, and was financially supported by Energinet.dk. The project work mainly involved conducting pilot-scale experiments in the CHEC entrained flow reactor, carrying out full-scale aerosol measurements at the Esbjergværket (ESV), doing global equilibrium calculations, and performing thermogravimetric experiments. Through performing co-combustion experiments in the CHEC entrained flow reactor, the burnout, NO and SO2 emissions, the transformation of ash forming species, the formation of deposits, and the partitioning of trace elements during co-combustion of coal and solid recovered fuel (SRF) were studied systematically. The effect of different coal properties, SRF properties, and mass share of SRF on co-combustion was investigated. Besides, global equilibrium calculations were conducted to interpret the results of the entrained flow experiments. The formation of fine particles during cocombustion of coal and SRF was also investigated, through performing full-scale aerosol measurements at the Esbjergværket (ESV). The influence of co-combustion on the concentration and composition of the fine particles was evaluated, and the impact on the dust emissions was discussed. In addition, a fundamental study on the interactions of coal and different waste materials during pyrolysis was conducted through thermogravimetric experiments. In general, the results obtained from this project have significantly improved the understandings of fuel conversion, ash transformation, ash deposition, and pollutant formation during co-combustion of coal and refuse derived fuels. These results have also provided essential knowledge regarding the fuel selection and process optimization of co-firing refuse derived fuels and coal under suspension-firing conditions.
Quantification of Ash Deposit Build-up and Removal in a Straw and Wood Suspension-Fired Boiler

The aim of this study was to investigate ash deposit formation rate, heat uptake reduction and deposit removal by using advanced online ash deposition and sootblowing probes in a 350 MWth suspension-fired boiler, utilizing wood and straw pellets as fuel. The influence of fuel type (straw share in wood), probe exposure time, probe surface temperature (500, 550 and 600 oC) and flue gas temperature (600 -1050 oC) on ash deposit formation rate, heat uptake by the probe, the fly ash and deposit characteristics, and deposit removal have been investigated. A systematic mathematical procedure was used to determine derivative deposit formation (DDF) rate. The overall derivative deposit formation (DDF) rates were measured to be between 0 to 3200 g/m2h. Large differences in the DDF rates are observed without the causes presently known. However, the results indicated that an increase in flue gas temperature increases the ash deposit formation rate. It was also found that probe heat uptake reduction was not strongly sensitive to the deposit mass load on the probe. This indicated that the heat transfer from the flue gas to the probe was dominated by the rear side, where little ash material was accumulated while the deposit mass load was very high on the flue gas facing side of the probe. Results of deposit removal by using sootblowing probe indicated that probe exposure time and surface temperature significantly influence the Peak Impact Pressure (PIP) needed to remove the deposits. The video recordings of all deposit probe experiments revealed that deposit shedding was primarily through debonding from the surface of the tubes in the superheater region. Chemical analysis of fly ashes indicated that during suspension-firing of straw and wood, the fly ashes were rich in Si, K, Ca and Cl, but the relative percentage of volatile elements (K, Cl and S) was much less compared to grate-firing conditions. The chemical analysis of the deposits showed that the inner most layers was dominated by contents of K, Cl and S compared to the upper layers rich in K and Si.
Release and Transformation of Inorganic Elements in Combustion of a High-Phosphorus Fuel

The release and transformation of inorganic elements during grate-firing of bran was studied via experiments in a laboratory-scale reactor, analysis of fly ash from a grate-fired plant, and equilibrium modeling. It was found that K, P, S, and to a lesser extent Cl and Na were released to the gas phase during bran combustion. Laboratory-scale experiments showed that S was almost fully vaporized during pyrolysis below 700 °C. Sixty to seventy percent of the K and P in bran was released during combustion, in the temperature range 900–1100 °C. The release of K and P was presumably attributed to the vaporization of KPO3 generated from thermal decomposition of inositol phosphates, which were considered to be a major source of P and K in bran. The influence of additives such as CaCO3, Ca(OH)2, and kaolinite on the release was also investigated. Ca-based additives generally increased the molar ratio of the released K/P, whereas kaolinite showed an opposite effect. Thermodynamic modeling indicated that the fly ash chemistry was sensitive to the molar ratio of the released K/P. When the molar ratio of the released K/P was below 1, KPO3 and P4O10(g) were the main stable K and P species at temperatures higher than 500 °C. Below 500 °C, the KPO3 and P4O10 (g) may be converted to H3PO4(l), which may cause severe deposit build-up in the economizers of a grate-fired boiler. By increasing the molar ratio of the released K/P to above 2, the equilibrium distribution of the K and P species was significantly changed and the formation of H3PO4(l) was not predicted by thermodynamic modeling.

General information

State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Technical University of Denmark, Babcock & Wilcox Vølund A/S
Pages: 2874-2886
Publication date: 2011
Peer-reviewed: Yes

Publication information

Journal: Energy & Fuels
Volume: 25
Issue number: 7
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Solid fuel interactions in co-combustion: a literature survey

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Wu, H., Jappe Frandsen, F., Dam-Johansen, K.
Number of pages: 64
Publication date: 2011
Sulfur Release from Cement Raw Materials during Solid Fuel Combustion
During combustion of solid fuels in the material inlet end of cement rotary kilns, local reducing conditions can occur and cause decomposition of sulfates from cement raw materials. Decomposition of sulfates is problematic because it increases the gas-phase SO2 concentration, which may cause deposit formation in the kiln system. SO2 release from cement raw materials during combustion of solid fuels has been studied experimentally in a high temperature rotary drum. The fuels were tire rubber, pine wood, petcoke, sewage sludge, and polypropylene. The SO2 release from the raw materials was observed to increase when (a) the inlet oxygen concentration decreased, (b) the temperature increased, and (c) when the total surface area of the fuel particles increased. The type of fuel also had a significant effect on the SO2 release. The sequence of SO2 release for fuel particles in the size interval 1–2 mm was found to be tire rubber granulate > sewage sludge > pine wood sawdust > petcoke > polypropylene flakes. The SO2 release was generally observed to increase when formation of local reducing conditions near the raw material bed increased, as indicated by elevated levels of CO during the fuel devolatilization.
Synthesis of durable microcapsules for self-healing anticorrosive coatings: A comparison of selected methods

Self-healing materials have the ability to ‘repair’ themselves upon exposure to an external stimulus. In the field of coatings, extensive laboratory research has been conducted on these so-called smart materials in the last decade. In the present work, a self-healing concept for epoxy-based anticorrosive coatings, based on incorporation of microcapsules, filled with reactive agents, into the coating matrix, is investigated. Upon small damages to the coating, the reagents are released from the capsules and react, thereby forming a cross-linked network, which heals the crack. However, for the concept to work, microcapsules have to be strong enough to remain intact during storage and coating formulation and application. Furthermore, the capsules must remain stable for many years in the dry coating. Laboratory experiments, using four out of several encapsulation methods available in the literature, have been conducted to investigate the challenges associated with the synthesis of stable microcapsules. It was found that the nature of the core material strongly affects the microcapsule stability and performance. Furthermore, it was evident that experimental procedures developed for certain core materials were not suitable for encapsulation of other compounds without modifications. This is a severe limitation as not many of the encapsulation procedures have been developed for industrially relevant core materials such as epoxy resin. Results of experiments, aiming at finding optimal conditions for robust microcapsule production, are discussed.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Nesterova, T., Dam-Johansen, K., Kiil, S.
Pages: 342-352
Publication date: 2011
Global equilibrium calculations have been performed to study the behavior of ash forming species in co-combustion of a bituminous coal and a solid recovered fuel (SRF). It revealed that co-combustion of coal and 25% SRF (weight basis) could significantly reduce the formation of NaCl (g) and KCl (g) in moderate temperature (800–1000 °C), as compared with that in 100% SRF combustion. The simulation results were compared with the experiment results obtained at the same fuel condition, and qualitative agreements were achieved. Both results suggest that co-combustion of coal and SRF would be a feasible method to increase the electrical efficiency of utilizing waste, as the aluminosilicates content in the coal could mitigate the ash related problems caused by the relative high chlorine and alkali content in the SRF. The influence of different SRF quality on the behavior of co-combustion was evaluated through adding PVC and NaCl to the fuel mixture. Both the simulation and experimental results indicate that formation of NaCl (g) and KCl (g) at temperatures above 1000 °C is significantly increased with the addition of PVC and NaCl. And a large fraction of the formed NaCl (g) and KCl (g) is not converted to aluminosilicates during the flue gas cooling in the experiments, probably due to kinetic limitations. The results suggest that it is important to control the chlorine and alkali content in SRF, in order to facilitate co-combustion of coal and SRF.

Alternative fuel combustion in cement rotary kilns

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Number of pages: 2
Publication date: 2010
Peer-reviewed: No
Source: orbit
Source-ID: 266207
Research output: Research › Conference abstract for conference – Annual report year: 2010
Antifouling effect of hydrogen peroxide release from enzymatic marine coatings: Exposure testing under equatorial and Mediterranean conditions

Hydrogen peroxide (H2O2) may be considered an environmentally friendly antifouling alternative to common biocides such as Cu2O and various organic compounds. In this work, the efficiency of antifouling coatings releasing hydrogen peroxide via enzyme-mediated conversion of starch, under Mediterranean and equatorial climatic conditions, is investigated. During seawater exposure of the coatings, starch is first converted to glucose by glucoamylase (rate-controlling step) and subsequently glucose is rapidly oxidised by hexose oxidase in a reaction producing hydrogen peroxide. The coatings formulated have been characterised in terms of common coating characteristics and immersed on rafts in seawater outside Singapore and Spain to monitor antifouling efficiency. The results have been compared to results previously reported from temperate waters in the North Sea outside The Netherlands. Using laboratory assays, the transient hydrogen peroxide release rate from the coatings at different temperatures has been measured. The investigations are used to evaluate the ocean performance of the antifouling coatings. Coatings can be formulated with starch/enzyme 'pigments' in considerable amounts and yet retain the mechanical properties required of an antifouling coating. However, the antifouling effect of the coatings immersed in seawater near Singapore and Spain, when inspected after 8 and 14 weeks, respectively, is insufficient. In comparison, previous studies under colder conditions showed an effect exceeding that of two commercial references over 67 days. The release rate of hydrogen peroxide from the coatings is shown to be greatly influenced by temperature, and therefore the results provided here suggest an antifouling effect that is highly dependent on the environment of the coating.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Olsen, S., Kristensen, J., Laursen, B., Pedersen, L., Dam-Johansen, K., Kiil, S.
Pages: 248-257
Publication date: 2010
Peer-reviewed: Yes

Publication information
Journal: Progress in Organic Coatings
Volume: 68
Issue number: 3
ISSN (Print): 0300-9440
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): SJR 0.844 SNIP 1.288
Web of Science (2017): Impact factor 2.955
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.89 SJR 0.852 SNIP 1.335
Web of Science (2016): Impact factor 2.858
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.84 SJR 0.857 SNIP 1.384
Web of Science (2015): Impact factor 2.632
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.8 SJR 0.997 SNIP 1.585
Web of Science (2014): Impact factor 2.358
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.58 SJR 1.03 SNIP 1.642
Web of Science (2013): Impact factor 2.302
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
A passive apparatus for controlled-flux delivery of biocides: hydrogen peroxide as an example

A new test method has been developed to estimate the required release rate of hydrogen peroxide (H2O2) to prevent marine biofouling. The technique exploits a well-defined concentration gradient of biocide across a cellulose acetate membrane. A controlled flux of H2O2, an environmentally friendly biocide, was obtained. Larvae of the barnacle, Balanus improvisus, were subjected to known release rates of H2O2 from a surface, under laboratory conditions. It was found that the distribution of settled larvae was not significantly different from the controls when H2O2 fluxes of 5-8 μg cm⁻² day⁻¹ were applied. However, release rates of 40 μg cm⁻² day⁻¹ significantly displaced the distribution of settled larvae towards the area of the chamber farthest away from the membrane. Membrane tests in seawater (Jyllinge Harbour, Denmark) for over 16 weeks showed that release rates of H2O2 of approximately 2800 μg cm⁻² day⁻¹ deterred biofouling efficiently. A H2O2 release rate of about 224 μg cm⁻² day⁻¹ resulted in some slime formation, but it was less than that on the H2O2-free control. It appears that to obtain efficient resistance to biofouling in natural seawater requires much higher membrane release rates of H2O2 (factor of between 5 and 50) than laboratory membrane exposure assays using barnacle larvae.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Hempel A/S
Ash behavior in the combustion of phosphorus rich biofuels - literature survey and experimental studies

Utilization of biofuels such as grain, bran and rapeseed meal in energy production is considered to have ecological and economical benefits. These seed-originated biofuels usually contain significantly higher phosphorus contents than other biofuels, which may induce some ash related operation problems. In this report, the behaviors of inorganic species during the combustion of phosphorus rich biofuels are studied through literature review and experiments. It is found that the majority of P, Mg and K in these biofuels would be present as phytic acid/phytate or other inositol phosphate. During the combustion of phosphorus rich biofuels, the K, P, and S are the main inorganic species released to the gas phase. The release of K and P occurs in a temperature range of 900-1100 °C, and the primarily reason is attributed to the vaporization of phosphate compounds. The addition of Kaolin and Ca-based additives shows some retention effects on the K or P release. By performing thermodynamic calculations, the interactions among the released K, P, and S in the flue gas are investigated, showing that the ash chemistry would be significantly affected by the molar ratio of the released K/P. The results from the thermodynamic calculations are supported by some experimental findings, and are used to explain some practical problems observed in the combustion of bran in a grate-fired power plant. Other operational problems related with the combustion of phosphorus rich biofuels are also discussed and the possible countermeasures are suggested.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Technical University of Denmark, Babcock & Wilcox Valund A/S
Publication date: 2010

Publication information
Publisher: Technical University of Denmark, Department of Chemical Engineering
Original language: English
Source-ID: u::8594
Research output: Research › Report – Annual report year: 2010

Ash Deposit Formation and Removal in a Straw and Wood Suspension-Fired Boiler

Utilization of biomass on large suspension-fired boilers is a potentially efficient method to reduce net CO2 emissions and reduce the consumption of fossil fuels. However, ash deposit formation on heat transfer surfaces may cause operational problems and in severe cases lead to boiler stop and manual cleaning. Most studies on ash deposition and removal has been done on biomass grate boilers, while only limited data is available from biomass suspension-firing. The aim of this study was to investigate deposit mass uptake, heat uptake reduction, deposit characteristics, and deposit removal by using an advanced online deposit probe in a full scale suspension-fired boiler using wood and straw pellets as fuel (Amageværket Unit 2, AMV2). The 250 MWth boiler has maximum capacity of 60t/h biomass, owned by Vattenfall, and located in Copenhagen, Denmark. The maximum operation period of boiler was limited to two weeks when 100% straw was fired due to ash deposition in the superheater region that has tube spacing specified for coal-firing (113mm). A series of 3-5 days deposit probe experiments were conducted utilizing 35 to 100% straw with wood on mass basis. The applied deposit probe was water and air cooled, and it was possible to register deposit mass uptake, heat uptake, and flue gas temperature. The surface temperature of the probe was kept at 500 °C and in some of the experiments, a CCD camera registered the deposit formation and removal process on the probe. The probe was placed in the superheater region (1st draught, flue gas temperature, 820-865 °C) and in the tube bank region (2nd draught, flue gas temperature, 580-605 °C). The percentage of ash in the applied straw and wood was 5.9 % and 3.3 %, while the K contents were 0.81% and 0.09% respectively. During 35% straw share, the initial two hours deposit mass uptake rate was 52.8 (g/m2/h), while it was 353.8 (g/m2/h) during 100% straw-firing. All tests in the superheater region for all applied straw shares indicated that with
increase in straw share, final deposit mass uptake increased. The comparison of current and previous full scale experimental studies conducted by CHEC indicated that there was not a big difference regarding final deposit mass uptake during straw suspension-firing and combustion on grate. The shedding (deposit removal) events were investigated when the nearby plant sootblower was shutdown. It was identified that the mass uptake signal increased linearly and then suddenly dropped when a complete layer of deposits was removed. The shedding events were confirmed through imaging data collected through a CCD camera and a complete layer of deposits removed can be clearly identified (shedding through debonding). The shedding investigation was also made when the nearby plant sootblower (4m below) was working. It was identified that the mass uptake signal remained stable and the deposits in small pieces were continuously removed during 35% and 65% straw-firing. Previous findings of Vattenfall indicated that a mixture of 50% straw with wood gave up to more than one month of continuous boiler operation, because plant sootblowers made the boiler operation stable. During 80% and 100% straw-firing, deposits were removed in small pieces but overall deposit weight uptake signal increased. The probe heat uptake reduction, in the superheater region, was reasonably similar for all applied straw shares. Even with a significant deposit build up on the windward probe direction, heat uptake remained approximately constant. This indicated that the heat transfer from the flue gas to the probe was dominated along the rear side, where little material was accumulated. Elemental analysis of the fuel ash, fly ash and deposit samples was made using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) to determine elemental percentage of Al, Ca, Fe, K, Mg, Na, P, Si, S and Cl. Elemental composition of fly ash samples during straw suspension-firing indicated significant amounts of Si and Ca, compared to grate-firing fly ashes that has a higher content of K and Cl. Elemental analysis of the probe front side deposits indicated that the amount of K and Cl increased by increasing straw share, while Ca contents decreased. It was found that increased deposit surface temperature (> 550 °C) caused reduction of the Cl contents in the front layer of deposits. Based on the current findings, recommendations for the optimal operation strategy of straw and wood suspension-fired boilers with respect to minimization of deposit related problems could be provided.
Cathodic delamination of seawater-immersed anticorrosive coatings: Mapping of parameters affecting the rate

Abstract: Cathodic delamination is one of the major modes of failure for organic coatings immersed in seawater and refers to the weakening or loss of adhesion between the coating and the substrate. The diminished adhesion is the result of electrochemical reactions occurring at the coating-steel interface, where solid iron is oxidized to ferrous ions and oxygen is reduced to hydroxyl ions. In this work, the effects of various parameters on cathodic delamination have been investigated. The parameters are: permeability of the coating, concentration of dissolved oxygen and cations, polarization potential, type of binder, degree of curing, and pigment loading, shape and type. The results show that cathodic delamination increases with increasing concentration of cations up to the point where the concentration of dissolved oxygen becomes insufficient to maintain the corrosion rate. The rate of cathodic delamination is inversely proportional to the magnitude of polarization potential when ions can penetrate the coating, while cathodic polarization does not affect cathodic delamination when the ionic transport is restricted to the coating-steel interface. Increasing the pigment loading or partial replacement of spherical pigments with flake-shaped micaceous iron oxide or aluminium pigments reduces the rate of cathodic delamination. Finally, binders with an increasing amount of secondary hydroxyl groups in the polymer backbone reduce the rate of cathodic delamination while increasing the initial molar ratio of amide to epoxide increases cathodic delamination. (C) 2010 Elsevier B.V. All rights reserved.
Cathodic delamination: Quantification of ionic transport rates along coating-steel interfaces

So-called cathodic delamination is one of the major modes of failure for organic coatings immersed in electrolyte solutions (e.g. seawater). Cathodic delamination occurs as a result of the electrochemical reactions which take place on a corroding steel surface. This means that reactants must continuously be transported from the bulk solution to the cathodic areas. The transport of sodium ions from a defect in the coating to the cathodic areas is generally considered the rate-determining step for cathodic delamination because the transport of oxygen and water through the coating is sufficient for the corrosion processes. In this work, a novel practical method, which allows direct estimation of the apparent diffusion coefficient of sodium ions in the ultrathin aqueous layer at the coating-steel interface, is described. The apparent diffusion coefficients estimated are of similar magnitude as previously reported values and show an acceptable repeatability. The method was used to obtain the apparent diffusion coefficients of sodium ions in the coating-steel interface for three commercial inert-pigmented epoxy coatings. The delamination rates predicted using the apparent interfacial diffusion coefficients and Fick's second law, under the assumption of a transport controlled mechanism, show qualitative agreement with the observed delamination rates in 0.5 M sodium chloride. This confirms that the rate-determining step of cathodic delamination is the transport of sodium ions along the coating-steel interface. (C) 2009 Elsevier B.V. All rights reserved.
Cathodic delamination: Quantification of Ionic transport rates along coating-steel interfaces

So-called cathodic delamination is one of the major modes of failure for organic coatings immersed in electrolyte solutions (e.g. seawater). Cathodic delamination occurs as a result of the electrochemical reactions, which takes place on a corroding steel surface. This means that reactants must continuously be transported from the bulk solution to the cathodic areas. The transport of sodium ions from a defect in the coating to the cathodic areas is generally considered the rate-determining step for cathodic delamination because the transport of oxygen and water through the coating is sufficient for the corrosion processes. In this work, a novel practical method, which allows direct estimation of the apparent diffusion coefficient of sodium ions in the ultrathin aqueous layer at the coating-steel interface, is described. The apparent diffusion coefficients estimated are of similar magnitude as previously reported values and show an acceptable repeatability. The method was used to obtain the apparent diffusion coefficients of sodium ions in the coating-steel interface for three commercial inert-pigmented epoxy coatings. The delamination rates predicted using the apparent interfacial diffusion coefficients and Fick's second law, under the assumption of a transport-controlled mechanism, show qualitative agreement with the observed delamination rates in 0.5 M sodium chloride. This confirms that the rate-determining step of cathodic delamination is the transport of sodium ions along the coating-steel interface.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Sørensen, P., Dam-Johansen, K., Weinell, C., Kiil, S.
Pages: 70-78
Publication date: 2010
Peer-reviewed: Yes

Publication information
Journal: Progress in Organic Coatings
Volume: 68
Issue number: 1-2
ISSN (Print): 0300-9440
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): SJR 0.844 SNIP 1.288
Web of Science (2017): Impact factor 2.955
Keywords: Disbondment, Protective coatings, Accelerated testing, Corrosion, Disbonding

10.1016/j.porgcoat.2009.08.018
Characterization and Quantification of Deposits Buildup and Removal in Biomass Suspension-Fired Boilers

Utilization of biomass as wood or straw in large suspension-fired boilers is an efficient method to reduce the use of fossil fuels consumption and to reduce the net CO2 formation. However, the presence of chlorine and alkali metals in biomass (straw) generate ash with a low melting point and induce large problems of ash deposit formation on the superheater tubes. Full scale studies on biomass ash deposition and removal had been done on biomass grate boilers, while only limited data is available from biomass suspension-firing. The aim of this study was to investigate deposit mass uptake, heat uptake reduction, fly ash and deposit characteristics, and deposit removal by using an advanced online deposit probe in a suspension-fired boiler using wood and straw pellets as fuel. The influence of fuel type and probe exposure time on the ash deposition rate, the heat uptake, the fly ash and deposit characteristics, and deposit removal have been investigated. The final deposit mass signal after a residence time of 3 to 5 days region was 1041, 1475, 1520 and 1670 g/m² for 35, 65, 80 and 100% straw share respectively in the superheater region (flue gas temperature, 800-900 °C), while the mass uptake was very small in the tube bank region (flue gas temperature, 550-605 °C) during pure wood-firing. It was found that during suspension-firing of pure straw at low boiler load, the overall weight uptake is comparable with grate-firing, even though the amount of fly ash generated was significantly higher during suspension-firing. Deposit removal through debonding was the main mechanism of deposit shedding when no plant sootblower was in operation. Elemental analysis of fly ashes and deposit samples was made in order to determine concentrations of the major elements Al, Ca, Fe, K, Mg, Na, P, Si, S and Cl. It was identified that the straw suspension-firing fly ashes contain high contents of Si and Ca, while grate-firing fly ashes contain higher contents of volatile elements K, Cl and S.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Vattenfall Vindkraft A/S
Pages: 1094-1100
Publication date: 2010

Host publication information
Title of host publication: Proceedings of the 18th European Biomass Conference
Publisher: ETA-Florence Renewable Energies
ISBN (Print): 978-88-89407-56-1
Keywords: Fouling, Deposits, Fly ashes, Slagging, Biomass
DOIs:
10.5071/18thEUBCE2010-OA5.1
URLs:
http://www.etaflorence.it/proceedings/?detail=6041
Source: orbit
Source-ID: 318748
Research output: Research - peer-review › Article in proceedings – Annual report year: 2010

CO2 Capture by Carbonate Looping

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Dam-Johansen, K.
Number of pages: 2
Pages: 154-155
Publication date: 2010

Host publication information
Title of host publication: Proceedings of Dansk Kemiingeniørkonference
Source: orbit
Source-ID: 266176
Research output: Research › Conference abstract in proceedings – Annual report year: 2010

Co-combustion of solid recovered fuel with coal in an entrained flow reactor and the effect of additives: The 35th International Technical Conference on Clean Coal & Fuel Systems

General information
Effect and Modeling of Glucose Inhibition and In Situ Glucose Removal During Enzymatic Hydrolysis of Pretreated Wheat Straw

The enzymatic hydrolysis of lignocellulosic biomass is known to be product-inhibited by glucose. In this study, the effects on cellulolytic glucose yields of glucose inhibition and in situ glucose removal were examined and modeled during extended treatment of heat-pretreated wheat straw with the cellulolytic enzyme system, Celluclast (R) 1.5 L, from Trichoderma reesei, supplemented with a beta-glucosidase, Novozym (R) 188, from Aspergillus niger. Addition of glucose (0-40 g/L) significantly decreased the enzyme-catalyzed glucose formation rates and final glucose yields, in a dose-dependent manner, during 96 h of reaction. When glucose was removed by dialysis during the enzymatic hydrolysis, the cellulose conversion rates and glucose yields increased. In fact, with dialytic in situ glucose removal, the rate of enzyme-catalyzed glucose release during 48-72 h of reaction recovered from 20-40% to become approximate to 70% of the rate recorded during 6-24 h of reaction. Although Michaelis-Menten kinetics do not suffice to model the kinetics of the complex multi-enzymatic degradation of cellulose, the data for the glucose inhibition were surprisingly well described by simple Michaelis-Menten inhibition models without great significance of the inhibition mechanism. Moreover, the experimental in situ removal of glucose could be simulated by a Michaelis-Menten inhibition model. The data provide an important base for design of novel reactors and operating regimes which include continuous product removal during enzymatic hydrolysis of lignocellulose.
Improved electrical efficiency and bottom ash quality on waste combustion plants

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Residual Resource Engineering, Department of Environmental Engineering, Department of Civil Engineering, Babcock & Wilcox Vølund A/S
Contributors: Jensen, P. A., Dam-Johansen, K., Frandsen, F., Bøjer, M., Kløft, H., Nesterov, I., Hyks, J., Astrup, T., Lundtorp, K., Madsen, O. H.
Number of pages: 18
Publication date: 2010

Publication information
Original language: English
Electronic versions:
Final resume report.pdf
Source: orbit
Source-ID: 263178
Research output: Research - peer-review › Journal article – Annual report year: 2010

Investigation of industrial Portland cement clinker formation and improvement of the burning technology

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Technical University of Denmark
Contributors: Telschow, S., Frandsen, F., Wedel, S., Dam-Johansen, K., Theisen, K.
Number of pages: 2
Publication date: 2010
Peer-reviewed: No
Source: orbit
Source-ID: 266225
Research output: Research › Conference abstract for conference – Annual report year: 2010

Kernediscipliner i Aktivt Samspil med Anvendelser

General information
Reactor design for minimizing product inhibition during enzymatic lignocellulose hydrolysis II. Quantification of inhibition and suitability of membrane reactors

Product inhibition of cellulolytic enzymes affects the efficiency of the biocatalytic conversion of lignocellulosic biomass to ethanol and other valuable products. New strategies that focus on reactor designs encompassing product removal, notably glucose removal, during enzymatic cellulose conversion are required for alleviation of glucose product inhibition. Supported by numerous calculations this review assesses the quantitative aspects of glucose product inhibition on enzyme-catalyzed cellulose degradation rates. The significance of glucose product inhibition on dimensioning of different ideal reactor types, i.e. batch, continuous stirred, and plug-flow, is illustrated quantitatively by modeling different extents of cellulose conversion at different reaction conditions. The main operational challenges of membrane reactors for lignocellulose conversion are highlighted. Key membrane reactor features, including system set-up, dilution rate, glucose output profile, and the problem of cellobiose are examined to illustrate the quantitative significance of the glucose product inhibition and the total glucose concentration on the cellulolytic conversion rate. Comprehensive overviews of the available literature data for glucose removal by membranes and for cellulose enzyme stability in membrane reactors are given. The treatise clearly shows that membrane reactors allowing continuous, complete, glucose removal during enzymatic cellulose hydrolysis, can provide for both higher cellulose hydrolysis rates and higher enzyme usage efficiency (kg(product)/kg(enzyme)). Current membrane reactor designs are however not feasible for large scale operations. The report emphasizes that the industrial realization of cellulosic ethanol requires more focus on the operational feasibility within the different hydrolysis reactor designs, notably for membrane reactors, to achieve efficient enzyme-catalyzed cellulose degradation. (C) 2010 Elsevier Inc. All rights reserved.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Center for BioProcess Engineering, CHEC Research Centre
Pages: 407-425
Publication date: 2010
Peer-reviewed: Yes

Publication information
Journal: Biotechnology Advances
Volume: 28
Issue number: 3
ISSN (Print): 0734-9750
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 12.05 SJR 3.006 SNIP 3.531
Web of Science (2017): Impact factor 11.452
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 11.05 SJR 2.747 SNIP 3.141
Web of Science (2016): Impact factor 10.597
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 10.56 SJR 2.915 SNIP 3.396
Web of Science (2015): Indexed yes
Reactor design for minimizing product inhibition during enzymatic lignocellulose hydrolysis: I. Significance and mechanism of cellobiose and glucose inhibition on cellulolytic enzymes

Achievement of efficient enzymatic degradation of cellulose to glucose is one of the main prerequisites and one of the main challenges in the biological conversion of lignocellulosic biomass to liquid fuels and other valuable products. The specific inhibitory interferences by cellobiose and glucose on enzyme-catalyzed cellulose hydrolysis reactions impose significant limitations on the efficiency of lignocellulose conversion especially at high-biomass dry matter conditions. To provide the base for selecting the optimal reactor conditions, this paper reviews the reaction kinetics, mechanisms, and significance of this product inhibition, notably the cellobiose and glucose inhibition, on enzymatic cellulose hydrolysis. Particular emphasis is put on the distinct complexity of cellulose as a substrate, the multi-enzymatic nature of the cellulolytic degradation, and the particular features of cellulase inhibition mechanisms and kinetics. The data show that new strategies that place the bioreactor design at the center stage are required to alleviate the product inhibition and in turn to enhance the efficiency of enzymatic cellulose hydrolysis. Accomplishment of the enzymatic hydrolysis at medium substrate concentration in separate hydrolysis reactors that allow continuous glucose removal is proposed to be the way forward for obtaining feasible enzymatic degradation in lignocellulose processing. (C) 2010 Elsevier Inc. All rights
Reduction of cathodic delamination rates of anticorrosive coatings using free radical scavengers

Cathodic delamination is one of the major modes of failure for anticorrosive coatings subjected to a physical damage and immersed in seawater. The cause of cathodic delamination has been reported to be the result of a chemical attack at the coating-steel interface by free radicals and peroxides formed as intermediates in the cathodic reaction during the corrosion process. In this study, antioxidants (i.e., free radical scavengers and peroxide decomposers) have been incorporated into various generic types of coatings to investigate the effect of antioxidants on the rate of cathodic delamination of epoxy coatings on cold rolled steel. The addition of <5 wt% free radical scavengers to epoxy coatings improved the resistance toward cathodic delamination by up to 50% during seawater immersion, while peroxide decomposers had a limited effect. Testing using substrates prepared from stainless steel, copper, aluminum, galvanized steel, and brass also showed a reduction in the rate of cathodic delamination when the coating was modified with a free radical scavenger. The protective mechanism of free radical scavengers investigated for the primers are similar to that of antioxidants used for protection against photochemical degradation by UV-radiation of top coatings. Both substrate corrosion and degradation of a coating exposed to UV-radiation lead to the formation of free radicals as reactive intermediates.
**Release of Corrosive Species above the Grate in a Waste Boiler and the Implication for Improved Electrical Efficiency**

A relatively low electrical efficiency of 20–25% is obtained in typical west European waste boilers. Ash species released from the grate combustion zone form boiler deposits with high concentrations of Cl, Na, K, Zn, Pb, and S that cause corrosion of superheater tubes at high temperature. The superheater steam temperature has to be limited to around 425 °C, and thereby, the electrical efficiency remains low compared to wood or coal-fired boilers. If a separate part of the flue gas from the grate has a low content of corrosive species, it may be used to superheat steam to a higher temperature, and thereby, the electrical efficiency of the plant can be increased. In this study, the local temperature, the gas concentrations of CO, CO2, and O2, and the release of the volatile elements Cl, S, Na, K, Pb, Zn, Cu, and Sn were measured above the grate in a waste boiler to investigate if a selected fraction of the flue gas could be applied for increased steam superheating. On a 26 ton/h grate-fired waste boiler, Vestforbrænding unit 5 in Denmark, local probe measurements were performed in five ports along the grate and in the top of the boiler chamber. New extraction probe equipment were designed and used to extract a flue gas with high contents of tar. Gas concentration measurements of O2, CO, and CO2 showed that the waste experienced pyrolysis and combustion on grate sections 1 and 2, some char combustion takes place on section 3, and the slag was cooled on sections 4 and 5. The measurements showed that the waste grate combustion process can provide a flue gas with a high energy content and a relatively low concentration of corrosive species. This opens up for the possibility of using an additional superheater section to increase the steam temperature and, thereby, increase electrical efficiency.
Replacement of traditional seawater-soluble pigments by starch and hydrolytic enzymes in polishing antifouling coatings

The use of starch and hydrolytic enzymes as replacement for traditional polishing pigments (e.g., Cu$_2$O and ZnO) in antifouling coatings has been investigated. The enzymes facilitate a slow conversion of water-insoluble starch into water-soluble glucose, and dissolution of glucose causes the development of a leached (porous) layer in the wetted, outermost part of the coating. Subsequent water-binder interaction at the pore walls gives rise to polishing, in a manner similar to that of conventional antifouling coatings. Different starch types have been evaluated and classified as potential coating ingredients, and the impact of the addition of starch on the functional properties of the coating is described. Starches from rice, corn, and tapioca have been tested, and due to a smaller amount of water-soluble content and lesser tendency to agglomerate, corn starch is preferred. Leaching occurs in all the starch-enzyme coatings tested; however, polishing is only detected for two out of four binder systems investigated. Suitable polishing rates of 7-10 μm/month, based on the enzymatic starch-degradation, have been measured. Controls containing only starch (no enzyme) did not polish.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Olsen, S. M., Pedersen, L. T., Dam-Johansen, K., Kristensen, J., Kiil, S.
Pages: 355-363
Publication date: 2010
Peer-reviewed: Yes

Publication information
Journal: Journal of Coatings Technology and Research
Volume: 7
Issue number: 3
ISSN (Print): 1547-0091
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.7 SJR 0.415 SNIP 0.894
Web of Science (2017): Impact factor 1.619
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.44 SJR 0.424 SNIP 0.658
Web of Science (2016): Impact factor 1.557
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.45 SJR 0.421 SNIP 0.794
Web of Science (2015): Impact factor 1.342
Web of Science (2015): Indexed yes
SO2 Emission from Modern Cement Plants

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, FLSmidth & Co. A/S
Contributors: Rasmussen, M. H., Wedel, S., Illerup, J. B., Dam-Johansen, K., Nielsen, H., Pedersen, K. H.
Number of pages: 2
Publication date: 2010
Peer-reviewed: No
Source: orbit
Source-ID: 266208
Research output: Research › Conference abstract for conference – Annual report year: 2010

Synthesis of durable microcapsules for self-healing anticorrosive coatings

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Nesterova, T., Dam-Johansen, K., Kiil, S.
Pages: 240-243
Publication date: 2010
**Synthesis of durable microcapsules for self-healing anticorrosive coatings.**

**General information**
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Nesterova, T., Kiil, S., Dam-Johansen, K.
Publication date: 2010
Peer-reviewed: Yes
Keywords: Synthesis, anticorrosive
Source: orbit
Source-ID: 275501
Research output: Research - peer-review › Poster – Annual report year: 2010

**The effect of low-NOx combustion on residual carbon in fly ash and its adsorption capacity for air entrainment admixtures in concrete**
Fly ash from pulverized coal combustion contains residual carbon that can adsorb the air-entraining admixtures (AEAs) added to control the air entrainment in concrete. This is a problem that has increased by the implementation of low-NOx combustion technologies. In this work, pulverized fuel has been combusted in an entrained flow reactor to test the impact of changes in operating conditions and fuel type on the AEA adsorption of ash and NOx formation. Increased oxidizing conditions, obtained by improved fuel-air mixing or higher excess air, decreased the AEA requirements of the produced ash by up to a factor of 25. This was due to a lower carbon content in the ash and a lower specific AEA adsorptivity of the carbon. The latter was suggested to be caused by changes in the adsorption properties of the unburned char and a decreased formation of soot, which was found to have a large AEA adsorption capacity based on measurements on a carbon black. The NOx formation increased by up to three times with more oxidizing conditions and thus, there was a trade-off between the AEA requirements of the ash and NOx formation. The type of fuel had high impact on the AEA adsorption behavior of the ash. Ashes produced from a Columbian and a Polish coal showed similar AEA requirements, but the specific AEA adsorptivity of the carbon in the Columbian coal ash was up to six times higher. The AEA requirements of a South African coal ash was unaffected by the applied operating conditions and showed up to 12 times higher AEA adsorption compared to the two other coal ashes. This may be caused by larger particles formed by agglomeration of the primary coal particles in the feeding phase or during the combustion process, which gave rise to increased formation of soot.

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Pedersen, K. H., Jensen, A. D., Dam-Johansen, K.
Pages: 208-216
Publication date: 2010
Peer-reviewed: Yes

**Publication information**
Journal: Combustion and Flame
Volume: 157
Issue number: 2
ISSN (Print): 0010-2180
Ratings:
- BFI (2019): BFI-level 2
- Web of Science (2019): Indexed yes
- BFI (2018): BFI-level 2
- Web of Science (2018): Indexed yes
- BFI (2017): BFI-level 2
- Scopus rating (2017): CiteScore 5.27 SJR 2.427 SNIP 2.176
- Web of Science (2017): Impact factor 4.494
- Web of Science (2017): Indexed yes
Aerosol formation during co-combustion of coal and solid recovered fuel in a pulverized coal-fired power plant

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, DONG Energy AS
Contributors: Wu, H., Pedersen, A. J., Glarborg, P., Frandsen, F., Dam-Johansen, K., Sander, B.
Publication date: 2009

Host publication information
Title of host publication: Joint Meeting of the Scandinavia-Nordic and French Sections of the Combustion Institute
Source: orbit
Source-ID: 256353
Research output: Research - peer-review › Article in proceedings – Annual report year: 2009

Anticorrosive coatings: a review
The main objective of this review is to describe some of the important topics related to the use of marine and protective coatings for anticorrosive purposes. In this context, "protective" refers to coatings for containers, offshore constructions, wind turbines, storage tanks, bridges, rail cars, and petrochemical plants while "marine" refers to coatings for ballast tanks, cargo holds and cargo tanks, decks, and engine rooms on ships. The review aims at providing a thorough picture of state-of-the-art in anticorrosive coatings systems. International and national legislation aiming at reducing the emission of volatile organic compounds (VOCs) have caused significant changes in the anticorrosive coating industry. The requirement for new VOC-compliant coating technologies means that coating manufacturers can no longer rely on the extensive track record of their time-served products to convince consumers of their suitability for use. An important aspect in the development of new VOC-compliant, high-performance anticorrosive coating systems is a thorough knowledge of the components in anticorrosive coatings, their interactions, their advantages and limitations, as well as a detailed knowledge on the failure modes of anticorrosive coatings. This review, which mainly deals with European experience and practice, includes a description of the different environments an anticorrosive coating system may encounter during service. In addition, examples of test methods and standards for determination of the performance and durability of anticorrosive coatings have been included. The different types of anticorrosive coatings are presented, and the most widely applied generic types of binders and pigments in anticorrosive coatings are listed and described. Furthermore, the protective mechanisms of barrier, sacrificial, and inhibitive coatings are outlined. In the past decades, several alternatives to organic solvent-borne coatings have reached the commercial market. This review also presents some of these technologies and discusses some of their advantages and limitations. Finally, some of the mechanisms leading to degradation and failure of organic coating systems are described, and the reported types of adhesion loss are discussed.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Hempel A/S
Contributors: Sørensen, P. A., Kiil, S., Dam-Johansen, K., Erik Weinell, C.
Pages: 135-176
Publication date: 2009
Peer-reviewed: Yes

Publication information
Journal: JCT Research
Volume: 6
Issue number: 2
ISSN (Print): 1547-0091
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.7 SJR 0.415 SNIP 0.894
Web of Science (2017): Impact factor 1.619
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Cathodic delamination: Quantification of ionic transport rates along coating-steel interfaces

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Hempel A/S
Contributors: Sørensen, P. A., Kiil, S., Dam-Johansen, K., Weinell, C.
Publication date: 2009

Host publication information
Title of host publication: Coatings Science Internation : Book of Abstracts
Source: orbit
Source-ID: 241691
Research output: Research - peer-review › Journal article – Annual report year: 2009
Co-combustion of coal and SRF in an entrained flow reactor: a preliminary study

Investigations on co-firing of SRF with two kinds of bituminous coal were carried out in an entrained flow reactor. The experimental results showed that co-combustion of coal and SRF increased the unburnt carbon in fly ashes. The emissions of NO and SO2 were reduced with an increasing share of SRF both due to the low nitrogen and sulphur contents in the SRF and the synergy effects of the fuels. Influences of co-combustion on the deposit formation rate on an air-cooled probe were rather different for the two coals. For COPRIB coal and SRF co-combustion, the deposit formation rate decreased slightly with an increasing share of SRF. For SAKLEI coal and SRF co-combustion, the deposit formation rate showed an increasing trend up to 10 mass percent of SRF, and started to decrease at a higher SRF share. By analyzing the ash samples, it has been found that the concentrations of some trace elements such as Cd, Cu, Pb and Zn were highly enriched in the fly ashes from coal and SRF co-combustion. The effect may due to there are more organically associated trace elements in SRF than coals, and the high Cl content in SRF may enhance the enrichment of trace elements in fly ashes.

Determining the elemental composition of fuels by bomb calorimetry and the inverse correlation of HHV with elemental composition

This article presents a method to obtain a simplified elemental analysis of an organic sample in which oxygen, nitrogen, and sulphur are lumped. The method uses a bomb calorimeter, water, and ash measurements combined with a numerical procedure based on a generalised equation for predicting higher heating value. By analysing pure organic substances, literature data, and fuels it is demonstrated that the method can provide hydrogen estimates within +/- 0.7% daf. and carbon and sum of oxygen, nitrogen, and sulphur estimates within +/- 2% daf. for fuels containing less than 90% ash db., 2% nitrogen daf., and 1% daf. sulphur.
Effektive korrosionshindrende malinger

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Hempel A/S
Contributors: Sørensen, P. A., Kiil, S., Dam-Johansen, K., Erik Weinell, C.
Pages: 16-18
Publication date: 2009
Peer-reviewed: Yes

Publication information
Journal: Dansk Kemi
Volume: 10
ISSN (Print): 0011-6335
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Web of Science (2007): Indexed yes
Web of Science (2004): Indexed yes
Original language: Danish
Source: orbit
Source-ID: 256366
Research output: Research - peer-review › Journal article – Annual report year: 2009

Energieffektiv og miljøvenlig produktion af cement

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, FLSmidth & Co. A/S
Contributors: Dam-Johansen, K., Illerup, J. B., Thomsen, K.
Publication date: 2009
Peer-reviewed: Yes

Publication information
Journal: Dansk Kemi
Volume: 90
Issue number: 2
ISSN (Print): 0011-6335
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Web of Science (2007): Indexed yes
Web of Science (2004): Indexed yes
Original language: Danish
Source: orbit
Source-ID: 256969
Research output: Research - peer-review › Journal article – Annual report year: 2009

Forsurende gasser i cementfabrikker

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Rasmussen, M. H., Illerup, J. B., Wedel, S., Dam-Johansen, K.
Pages: 19-21
Publication date: 2009
Influence of substrate topography on cathodic delamination of anticorrosive coatings

The cathodic delamination of a commercial magnesium silicate and titanium dioxide pigmented epoxy coating on abrasive cleaned cold rolled steel has been investigated. The rate of delamination was found to depend on interfacial transport from the artificial defect to the delamination front and thereby the substrate topography, whereas the coating thickness had little influence. The presence of a significant potential gradient between the anode and the cathode and the dependency of the delamination rate on the tortuosity of the steel surface suggests that cathodic delamination is controlled by migration of cations from the defect to the delamination front. This means that abrasive blasting, to some extent, can be applied to control and minimize the observed rate of cathodic delamination. The lifetime of the species causing disbondment suggested that sodium hydroxide or potassium hydroxide and not peroxide species or radicals are the causative agents at free corrosion potential (i.e. without impressed current).
Inorganic precursor peroxides for antifouling coatings

Modern antifouling coatings are generally based on cuprous oxide (Cu₂O) and organic biocides as active ingredients. Cu₂O is prone to bioaccumulation, and should therefore be replaced by more environmentally benign compounds when technically possible. However, cuprous oxide does not only provide antifouling properties, it is also a vital ingredient for the antifouling coating to obtain its polishing and leaching mechanism. In this paper, peroxides of strontium, calcium, magnesium, and zinc are tested as pigments in antifouling coatings. The peroxides react with seawater to create hydrogen peroxide and highly seawater-soluble ions of the metal. The goals have been to establish the antifouling potency of an...
antifouling coating that releases hydrogen peroxide as biocide, and to investigate the potential use of peroxides as water-soluble polishing and leaching pigments. The investigations have shown that it is possible to identify particulates that, when applied as pigments in antifouling coatings, will provide polishing and leaching rates comparable to those of Cu2O-based coatings. Furthermore, the combination of polishing and hydrogen peroxide leaching by a coating based on zinc peroxide in a suitable binder matrix provides antifouling properties exceeding those of a similar coating based entirely on zinc oxide.

**General information**

State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Hempel A/S
Contributors: Olsen, S., Pedersen, L., Hermann, M., Kill, S., Dam-Johansen, K.
Pages: 187-199
Publication date: 2009
Peer-reviewed: Yes

**Publication information**

Journal: JCT Research
Volume: 6
Issue number: 2
ISSN (Print): 1547-0091
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.7 SJR 0.415 SNIP 0.894
Web of Science (2017): Impact factor 1.619
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.44 SJR 0.424 SNIP 0.658
Web of Science (2016): Impact factor 1.557
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.45 SJR 0.421 SNIP 0.794
Web of Science (2015): Impact factor 1.342
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.5 SJR 0.512 SNIP 1.045
Web of Science (2014): Impact factor 1.298
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 1.46 SJR 0.522 SNIP 0.981
Web of Science (2013): Impact factor 1.28
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 1.39 SJR 0.568 SNIP 1.327
Web of Science (2012): Impact factor 1.094
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 1.24 SJR 0.511 SNIP 0.993
Web of Science (2011): Impact factor 1.121
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.607 SNIP 0.859
Web of Science (2010): Impact factor 1.056
BFI (2009): BFI-level 1
ITOB Final Report – CHEC Industrial Consortium on thermal Conversion of Fuels

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Frandsen, F., Dam-Johansen, K.
Number of pages: 88
Publication date: 2009

Publication information
Place of publication: DTU
Publisher: Department of Chemical and Biochemical Engineering
Original language: English
Source: orbit
Source-ID: 247129
Research output: Research - peer-review › Report – Annual report year: 2009

Lægemiddelproduktion - brugen af modellering og PAT

General information
State: Published
Organisations: Center for BioProcess Engineering, Department of Chemical and Biochemical Engineering, Computer Aided Process Engineering Center, Center for Microbial Biotechnology, Department of Systems Biology, CHEC Research Centre
Contributors: Gernaey, K., Sin, G., Eliasson Lantz, A., Woodley, J., Gani, R., Dam-Johansen, K.
Pages: 22-24
Publication date: 2009
Peer-reviewed: Unknown

Publication information
Journal: Dansk Kemi
Volume: 90
Issue number: 3
ISSN (Print): 0011-6335
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Web of Science (2007): Indexed yes
Web of Science (2004): Indexed yes
Original language: Danish
Source: orbit
Source-ID: 255700
Research output: Communication › Journal article – Annual report year: 2009

Low-emission combustion technologies
Modelling solid-convective flash pyrolysis of straw and wood in the Pyrolysis Centrifuge Reactor

Less than a handful of solid-convective pyrolysis reactors for the production of liquid fuel from biomass have been presented and for only a single reactor a detailed mathematical model has been presented. In this article we present a predictive mathematical model of the pyrolysis process in the Pyrolysis Centrifuge Reactor, a novel solid-convective flash pyrolysis reactor. The model relies on the original concept for ablative pyrolysis of particles being pyrolysed through the formation of an intermediate liquid compound which is further degraded to form liquid organics, char, and gas. To describe the kinetics of the pyrolysis reactions the Broido-Shafizadeh scheme is employed with cellulose parameters for wood and modified parameters for straw to include the catalytic effect of its alkali-containing ash content. The model describes the presented experimental results adequately for engineering purposes for both wood and straw feedstock even though conditions for ablative pyrolysis from a reaction engineering point of view are not satisfied. Accordingly, even though the concept of an ablatively melting particle may constitute a limiting case, it can still be used to model flash pyrolysis provided that the reacting particle continuously shed the formed char layer.
Web of Science (2015): Impact factor 3.249
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 4.36 SJR 1.865 SNIP 1.964
Web of Science (2014): Impact factor 3.394
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.42 SJR 1.666 SNIP 1.811
Web of Science (2013): Impact factor 3.411
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.66 SJR 1.516 SNIP 1.754
Web of Science (2012): Impact factor 2.975
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 4.74 SJR 1.759 SNIP 2.296
Web of Science (2011): Impact factor 3.646
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.914 SNIP 2.251
Web of Science (2010): Impact factor 3.84
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.728 SNIP 2.183
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.614 SNIP 2.137
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.361 SNIP 1.825
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.268 SNIP 1.991
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.214 SNIP 1.401
Scopus rating (2004): SJR 1.027 SNIP 1.665
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.659 SNIP 1.378
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.396 SNIP 0.775
Scopus rating (2001): SJR 0.455 SNIP 1.048
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.447 SNIP 0.958
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 0.429 SNIP 1.064

Original language: English
Keywords: Pyrolysis centrifuge reactor, Ablative, Solid convective, Flash pyrolysis, Biocrude, Bio-oil, Wheat straw, Pine wood, Modelling
DOIs:
10.1016/j.biombioe.2009.03.009
Source: orbit
Source-ID: 249167
Research output: Research - peer-review › Journal article – Annual report year: 2009
Post-treatment of Fly Ash by Ozone in a Fixed Bed Reactor

The residual carbon in fly ash produced from pulverized coal combustion can adsorb the air-entraining admixtures (AEAs) added to enhance air entrainment in concrete. This behavior of the ash can be suppressed by exposing the fly ash to oxidizing species, which oxidizes the carbon surface and thus prevents the AEA to be adsorbed. In the present work, two fly ashes have been ozonated in a fixed bed reactor and the results showed that ozonation is a potential post-treatment method that can lower the AEA requirements of a fly ash up to 6 times. The kinetics of the carbon oxidation by ozone was found to be fast. A kinetic model has been formulated, describing the passivation of carbon, and it includes the stoichiometry of the ozone consumption (0.8 mol of O$_3$/kg of C) and an ineffective ozone loss caused by catalytic decomposition. The simulated results correlated well with the experimental data.
Spray Drying of Suspensions for Pharma and Bio Products: Drying Kinetics and Morphology

An experimental investigation of the spray drying behavior of droplets containing excipients and carrier materials used in the pharmaceutical and biotechnological industries has been conducted. Specifically, rice starch suspensions with different amounts of TiO2, maltodextrin, dextrin, NaCl and Na2SO4 are dried. The drying rate is measured, and the morphology formation is mapped to obtain a more fundamental understanding of the drying process, which is very useful when designing product formulations. In the pilot spray dryer, droplet generation is based on the JetCutter technology and die droplets are dried under well-defined temperature and flow conditions. The droplets are sampled during drying to determine the drying rate, and the dried particles are collected for morphology analysis. The results show that reducing the water activity in a suspension of insolubles by adding various amounts of inorganic salts or carbohydrates causes an increase in the droplet temperature during spray drying resulting in a rather constant the drying rate. Further, the results show that small alterations in the droplet composition may significantly change the final particle morphology. The observed morphologies are discussed in detail.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Niro A/S, Novozymes AS
Contributors: Sloth, J., Jørgensen, K., Bach, P., Jensen, A. D., Kill, S., Dam-Johansen, K.
Pages: 3657-3664
Publication date: 2009
Peer-reviewed: Yes
The effect of combustion conditions in a full-scale low-NOx coal fired unit on fly ash properties for its application in concrete mixtures

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Technical University of Denmark
Pages: 180-185
Publication date: 2009
Peer-reviewed: Yes

Publication information
Journal: Fuel Processing Technology
Volume: 90
Issue number: 2
ISSN (Print): 0378-3820
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.46 SJR 1.453 SNIP 1.729
Web of Science (2017): Impact factor 3.956
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.15 SJR 1.397 SNIP 1.729
Web of Science (2016): Impact factor 3.752
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.09 SJR 1.501 SNIP 1.817
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.96 SJR 1.612 SNIP 2.167
The Role of CaO in SO2 Abatement in Cement Preheaters

General information

State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, FLSmidth & Co. A/S
Contributors: Rasmussen, M. H., Wedel, S., Illerup, J. B., Dam-Johansen, K., Thomsen, K.
Publication date: 2009
Peer-reviewed: No
Event: Abstract from 8th World Congress of Chemical Engineering, Montreal, Canada.
Source: orbit
Source-ID: 235528
Research output: Research › Conference abstract for conference – Annual report year: 2009

DOI: 10.1016/j.fuproc.2008.08.012
Source: orbit
Source-ID: 256961
Research output: Research › Journal article – Annual report year: 2009
Deposition of flame-made nanoparticles on porous media

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Swiss Federal Institute of Technology Zurich
Contributors: Elmøe, T. D., Grunwaldt, J., Dam-Johansen, K., Pratsinis, S. E.
Number of pages: 196
Publication date: Aug 2008

Publication information
Original language: English
Electronic versions:
Tobis Elmøe.pdf
Source: orbit
Source-ID: 227991
Research output: Research › Ph.D. thesis – Annual report year: 2008

In Situ Flash Pyrolysis of Straw

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Bech, N., Dam-Johansen, K., Jensen, P. A.
Number of pages: 222
Publication date: Aug 2008

Publication information
Publisher: FRYDENBERG A/S
ISBN (Print): 978-87-91435-68-4
Original language: English
Electronic versions:
Niels Bech.pdf
Source: orbit
Source-ID: 228002
Research output: Research › Ph.D. thesis – Annual report year: 2008

Alkali/chloride release during refuse incineration on a grate: Full-scale experimental findings
Waste to energy (WtE) plants are utilised for the production of heat and electricity. However, due to corrosion at super heater surfaces a relatively low 25% of the waste lower heating value can with the present technology be converted to electricity. High contents of Cl, Na, K, Zn, Pb and S in waste cause relatively high super heater corrosion rates. The Cl-content in waste is one of the key-factors for volatilisation of alkali and heavy metals in WtE plants. Little is known about the release of Cl, Na, K, Zn, Pb, and S along grate of waste incineration plants. The 26 t h(-1) WtE plant Vestforbraending unit S in Denmark was used for measurements of temperature, gas-concentration (O-2/CO/CO2), and sampling of gas phase Cl, Na, K, Pb, Zn, and S. Unit 5 has 6 ports distributed along the 13 in long grate between 1.5-1.8 in above the grate. Five of these ports were used for measurements. Two aqueous absorption systems containing a solution of NH3 or a solution of H2O2/HNO3 were used to collect the gaseous samples. Tar was found to condense in the sampling system at the ports near the fuel inlet. The experiments showed the majority of Cl, Na, and K to be volatised during the early stages of combustion. The maximum release of Cl, Na, and K was measured in port 2 as 177 ppm(nu), 71 ppm(nu) and 44 ppm(nu) respectively. The maximum average gas temperature of 1140 was measured in port 3 compared to the temperatures at ports 2 and 4 of 816 and 551 respectively. It has been suggested to use flue gas from the area of the grate near port 3 with a high temperature, that contains relatively low amounts of corrosive elements, and lead to a separate high temperature super heater and thus increase the electrical efficiency.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Department of Mechanical Engineering
Contributors: Bajer, M., Jensen, P. A., Frandsen, F., Dam-Johansen, K., Madsen, O. H., Lundtorp, K.
Pages: 528-539
Publication date: 2008
Peer-reviewed: Yes
A review of the interference of carbon containing fly ash with air entrainment in concrete

Industrial utilization of fly ash from pulverized coal combustion plays an important role in environmentally clean and cost effective power generation. Today, the primary market for fly ash utilization is as pozzolanic additive in the production of concrete. However, the residual carbon in fly ash may interfere with air entraining admixtures (AEAs) added to enhance air entrainment in concrete in order to increase its workability and resistance toward freezing and thawing conditions. The problem has increased with implementation of low-NOx combustion technologies. This review presents the past work carried out to identify the mechanisms causing the interactions between AEAs and fly ash in concrete mixtures, emphasizing the residual carbon. It has been shown that not only the amount, but also the properties of carbon, such as particle size and surface chemistry, has an impact on the adsorption capacity of AEAs. The type of fuel used in the combustion process influences the amount and properties of the residual carbon. Fly ash derived from bituminous coal has generally higher carbon content compared with fly ash produced from subbituminous coal or lignite, but shows a lower AEA adsorption capacity per mass of carbon. Cases reporting increased residual carbon content due to low-NOx combustion are described, together with observations from a pilot scale experiment, where increased AEA adsorption capacity of carbon appeared to relate with firing at low-NOx conditions. Post-treatment methods applied to improve fly ash quality are described in the review. Ozonation, thermal treatment and physical cleaning of carbon have been found to improve the fly ash performance for concrete utilization. Ultimately, recommendations for further work are outlined in the discussion.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Pedersen, K. H., Jensen, A. D., Skjøth-Rasmussen, M. S., Dam-Johansen, K.
Pages: 135-154
Publication date: 2008
Peer-reviewed: Yes

Publication information
Journal: Progress in Energy and Combustion Science
Volume: 34
Issue number: 2
ISSN (Print): 0360-1285
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 24.19 SJR 6.751 SNIP 9.626
Web of Science (2017): Impact factor 25.242
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 19.82 SJR 5.443 SNIP 9.119
Web of Science (2016): Impact factor 17.382
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 21.6 SJR 8.077 SNIP 10.2
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 21.55 SJR 7.426 SNIP 11.879
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 22.43 SJR 8.259 SNIP 12.951
Web of Science (2013): Impact factor 16.909
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 17.82 SJR 5.859 SNIP 12.194
Web of Science (2012): Impact factor 15.089
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 18.43 SJR 7.61 SNIP 11.61
Web of Science (2011): Impact factor 14.22
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 5.154 SNIP 9.996
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 4.706 SNIP 8.327
Web of Science (2008): Indexed yes
Scopus rating (2006): SJR 2.242 SNIP 6.862
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.645 SNIP 5.462
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.038 SNIP 5.195
Scopus rating (2003): SJR 1.977 SNIP 6.026
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 3.023 SNIP 4.128
Scopus rating (2001): SJR 2.131 SNIP 5.259
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 1.124 SNIP 3.894
Scopus rating (1999): SJR 1.072 SNIP 2.5
Original language: English
Keywords: fly ash, air entrainment, combustion, concrete
DOIs:
10.1016/j.pecs.2007.03.002
Source: orbit
Source-ID: 221505
Research output: Research - peer-review › Journal article – Annual report year: 2008

Catalogue of energy technologies

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Thermal Energy, Department of Mechanical Engineering, Systems Analysis Division. Management, Systems Analysis Division, Risø National Laboratory for Sustainable Energy, Information Service Department
High Electrical Efficiency by Dividing the Combustion Products

Initial kinetics of the direct sulfation of limestone

The initial kinetics of direct sulfation of Faxe Bryozo, a porous bryozoan limestone was studied in the temperature interval from 873 to 973 K in a pilot entrained flow reactor with very short reaction times (between 0.1 and 0.6 s). The initial conversion rate of the limestone - for conversions less than 0.3% - was observed to be significantly promoted by higher SO2 concentrations and lower CO2 concentrations, whereas O2 showed negligible influence. A mathematical model for the sulfation of limestone involving chemical reaction at calcite grain surfaces and solid-state diffusion of carbonate ions in calcite grains is established. The validity of the model is limited to the initial sulfation period, in which nucleation of the solid product calcium sulphate is not started. This theoretical reaction-diffusion model gives a good simulation of the initial kinetics of the direct sulfation of Faxe Bryozo. The intrinsic rate of the direct sulfation of the limestone is estimated to have an activation energy of about 25 kJ/mol and reaction orders of about 0.9 and -0.75 for SO2 and CO2, respectively. The diffusivity of carbonate ions in the surface layer of the calcite grain is estimated to be about three orders of magnitude higher than the diffusivity of carbonate ions in the inner lattice of calcite grain and have an activation energy of about 202 kJ/mol.
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.31 SJR 1.015 SNIP 1.331
Web of Science (2017): Impact factor 3.326
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.11 SJR 1.035 SNIP 1.29
Web of Science (2016): Impact factor 2.836
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.03 SJR 1.085 SNIP 1.428
Web of Science (2015): Impact factor 2.98
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.86 SJR 1.066 SNIP 1.337
Web of Science (2014): Impact factor 2.748
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.59 SJR 1.053 SNIP 1.355
Web of Science (2013): Impact factor 2.581
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.46 SJR 0.98 SNIP 1.437
Web of Science (2012): Impact factor 2.493
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 2.31 SJR 0.994 SNIP 1.248
Web of Science (2011): Impact factor 2.261
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.085 SNIP 1.404
Web of Science (2010): Impact factor 2.03
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.194 SNIP 1.437
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.282 SNIP 1.42
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.252 SNIP 1.337
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.486 SNIP 1.637
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.308 SNIP 1.625
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.292 SNIP 1.659
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.688 SNIP 1.572
Methanol oxidation in a flow reactor: Implications for the branching ratio of the CH3OH+OH reaction

The oxidation of methanol in a flow reactor has been studied experimentally under diluted, fuel-lean conditions at 650-1350 K, over a wide range of O2 concentrations (1%-16%), and with and without the presence of nitric oxide. The reaction is initiated above 900 K, with the oxidation rate decreasing slightly with the increasing O2 concentration. Addition of NO results in a mutually promoted oxidation of CH3OH and NO in the 750-1100 K range. The experimental results are interpreted in terms of a revised chemical kinetic model. Owing to the high sensitivity of the mutual sensitization of CH3OH and NO oxidation to the partitioning of CH3O and CH2OH, the CH3OH + OH branching fraction could be estimated as α = 0.10 +/- 0.05 at 990 K. Combined with low-temperature measurements, this value implies a branching fraction that is largely independent of temperature. It is in good agreement with recent theoretical estimates, but considerably lower than values employed in previous modeling studies. Modeling predictions with the present chemical kinetic model is in quantitative agreement with experimental results below 1100 K, but at higher temperatures and high O2 concentration the model underpredicts the oxidation rate.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Rasmussen, C. L., Wassard, K., Dam-Johansen, K., Glarborg, P.
Pages: 423-441
Publication date: 2008
Peer-reviewed: Yes

Publication information
Journal: International Journal of Chemical Kinetics
Volume: 40
Issue number: 7
ISSN (Print): 0538-8066
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.43 SJR 0.543 SNIP 0.755
Web of Science (2017): Impact factor 1.416
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.47 SJR 0.392 SNIP 0.797
Web of Science (2016): Impact factor 1.386
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.01 SJR 1.007 SNIP 0.988
Web of Science (2015): Impact factor 1.736
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
New Cement Production Technology: Status report to the Advanced Technology Foundation

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Illerup, J. B., Dam-Johansen, K.
Publication date: 2008

Publication information
Publisher: Institut for Kemiteknik, DTU
Original language: English
Source: orbit
Source-ID: 221465
DOI: 10.1002/kin.20323
Research output: Research - peer-review » Journal article – Annual report year: 2008
Oriented nucleation and growth of anhydrite during direct sulfation of limestone

The direct sulfation of limestone (Iceland Spar) was studied at 973 K in a fixed-bed reactor. Scanning electron microscopy examinations of the sulfated limestone particles show that the sulfation process involves oriented nucleation and growth of the solid product, anhydrite. The reason for the occurrence of oriented nucleation and growth of the solid product is related to a close two-dimensional lattice match between the lattice plane \( \{1,0,4\} \) of calcite and the lattice plane \( \{(1/\overline{1},0)\} \) of anhydrite.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Hu, G., Dam-Johansen, K., Wedel, S.
Pages: 1181-1185
Publication date: 2008
Peer-reviewed: Yes

Publication information
Journal: Crystal Growth & Design
Volume: 8
Issue number: 4
ISSN (Print): 1528-7483
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.93 SJR 1.154 SNIP 1.103
Web of Science (2017): Impact factor 3.972
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 4 SJR 1.177 SNIP 1.226
Web of Science (2016): Impact factor 4.055
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 4.48 SJR 1.261 SNIP 1.325
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 4.84 SJR 1.361 SNIP 1.463
Web of Science (2014): Impact factor 4.891
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 4.59 SJR 1.333 SNIP 1.443
Web of Science (2013): Impact factor 4.558
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 4.7 SJR 1.573 SNIP 1.573
Web of Science (2012): Impact factor 4.689
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 4.76 SJR 1.472 SNIP 1.565
Web of Science (2011): Impact factor 4.72
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.567 SNIP 1.42
Web of Science (2010): Impact factor 4.39
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.532 SNIP 1.564
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.557 SNIP 1.635
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.476 SNIP 1.633
Scopus rating (2006): SJR 1.433 SNIP 1.575
Scopus rating (2005): SJR 1.218 SNIP 1.503
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.05 SNIP 1.112
Scopus rating (2003): SJR 0.776 SNIP 1.059
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.546 SNIP 0.857
Original language: English
DOIs:
10.1021/cg0704403
Source: orbit
Source-ID: 221502
Research output: Research - peer-review › Journal article – Annual report year: 2008

Release of Potentially Corrosive Constituents from the Grate of a Waste-to-energy Boiler – A detailed investigation

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Bøjer, M., Jensen, P. A., Dam-Johansen, K., Madsen, O. H., Lundtorp, K.
Publication date: 2008

Host publication information
Title of host publication: Impacts of Fuel Quality on Power Production and the Environment
Place of publication: Banff, Canada
Source: orbit
Source-ID: 232079
Research output: Research - peer-review › Article in proceedings – Annual report year: 2008

Ablative Flash Pyrolysis of Straw and Wood: Bench-scale Results

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Publication date: 2007

Host publication information
Title of host publication: Proceedings
Source: orbit
Source-ID: 211010
Research output: Research - peer-review › Article in proceedings – Annual report year: 2007

Applicability of a fiber-supported catalyst on a buchwald-hartwig Amination reaction

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Christensen, H., Kiil, S., Dam-Johansen, K.
Pages: 956-965
Publication date: 2007
Peer-reviewed: Yes
Characterization of pigment-leached antifouling coatings using BET surface area measurements and mercury porosimetry

In this work BET surface area measurements and mercury porosimetry are used to characterize leached layers formed when seawater-soluble pigments (Cu₂O and ZnO) dissolve during accelerated leaching of simple antifouling coatings. Measurements on single-pigment coatings show that an increasing fraction of Cu₂O or ZnO pigment particles becomes unavailable for dissolution when the concentration of the pigment decreases in the coating and the interparticle distance in the binder matrix becomes larger. Experimental data for a coating initially containing a mixture of Cu₂O and TiO₂ pigments suggest that a substantial fraction of the smaller and inert TiO₂ particles may be lost from the coating upon dissolution of the larger Cu₂O particles. This inert particle translocation effect is important to take into account when interpreting polishing and leaching data and when developing mathematical models of antifouling coating behaviour because the active binder surface area and porosity of the leached layer are substantially increased. A similar effect was not observed for a coating with a mixture of ZnO and TiO₂ pigments. The two experimental methods are expected to be useful for practical analysis of leaching of seawater-soluble components from commercial antifouling coatings.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Kiil, S., Dam-Johansen, K.
Pages: 238-247
Publication date: 2007
Peer-reviewed: Yes

Publication information
Journal: Progress in Organic Coatings
Volume: 60
Issue number: 3
ISSN (Print): 0300-9440
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): SJR 0.844 SNIP 1.288
Web of Science (2017): Impact factor 2.955
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.89 SJR 0.852 SNIP 1.335
Web of Science (2016): Impact factor 2.858
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.84 SJR 0.857 SNIP 1.384
Web of Science (2015): Impact factor 2.632
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.8 SJR 0.997 SNIP 1.585
Web of Science (2014): Impact factor 2.358
Web of Science (2014): Indexed yes
Chemical Product Design – A Brief Overview

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Gani, R., Dam-Johansen, K.
Pages: 1-21
Publication date: 2007

Host publication information
Direct Sulfation of Limestone

The direct sulfation of limestone was studied in a laboratory fixed-bed reactor. It is found that the direct sulfation of limestone involves nucleation and crystal grain growth of the solid product (anhydrite). At 823 K and at low-conversions (less than about 0.5 %), the influences of SO2, O-2 and CO2 on the direct sulfation of limestone corresponds to apparent reaction orders of about 0.2, 0.2 and -0.5, respectively. Water is observed to promote the sulfation reaction and increase the apparent reaction orders of SO2 and O-2. The influence of O-2 at high O-2 concentrations (> about 15 %) becomes negligible. In the temperature interval from 723 K to 973 K, an apparent activation energy of about 104 kJ/mol is observed for the direct sulfation of limestone. At low temperatures and low conversions, the sulfation process is most likely under mixed control by chemical reaction and solid-state diffusion. The nucleation and crystal grain growth of the solid product, and this mixed control mechanism provide satisfactory explanations of the various phenomena related to the direct sulfation of limestone, such as porosity in the product layer, the variation of the apparent reaction orders of SO2, O-2 and CO2 with reaction conditions and the influence of water. (c) 2007 American Institute of Chemical Engineers.
Effects of substrate loading on enzymatic hydrolysis and viscosity of pretreated barley straw

In this study, the applicability of a "fed-batch" strategy, that is, sequential loading of substrate or substrate plus enzymes during enzymatic hydrolysis was evaluated for hydrolysis of steam-pretreated barley straw. The specific aims were to achieve hydrolysis of high substrate levels, low viscosity during hydrolysis, and high glucose concentrations. An enzyme system comprising Celluclast and Novozyme 188, a commercial cellulase product derived from Trichoderma reesei and a beta-glucosidase derived from Aspergillus niger, respectively, was used for the enzymatic hydrolysis. The highest final glucose concentration, 78 g/l, after 72 h of reaction, was obtained with an initial, full substrate loading of 15% dry matter weight/wt/wt (w/w DM). Conversely, the glucose yields, in grams per gram of DM, were highest at lower substrate concentrations, with the highest glucose yield being 0.53 g/g DM for the reaction with a substrate loading of 5% w/w DM after 72 h. The reactions subjected to gradual loading of substrate or substrate plus enzymes to increase the substrate levels from 5 to 15% w/w DM, consistently provided lower concentrations of glucose after 72 h of reaction; however, the initial rates of conversion varied in the different reactions. Rapid cellulose degradation was accompanied by rapid decreases in viscosity before addition of extra substrate, but when extra substrate or substrate plus enzymes were added, the viscosities of the slurries increased and the hydrolytic efficiencies decreased temporarily.

General information
State: Published
Organisations: Department of Chemistry, CHEC Research Centre, Department of Chemical and Biochemical Engineering, Microreactors, Department of Micro- and Nanotechnology
Contributors: Rosgaard, L., Andric, P., Dam-Johansen, K., Pedersen, S., Meyer, A.
Pages: 27-40
Publication date: 2007
Peer-reviewed: Yes

Publication information
Journal: Applied Biochemistry and Biotechnology
Volume: 143
Issue number: 1
ISSN (Print): 0273-2289
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.02 SJR 0.571 SNIP 0.8
Web of Science (2017): Impact factor 1.797
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.81 SJR 0.579 SNIP 0.749
Web of Science (2016): Impact factor 1.751
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.67 SJR 0.575 SNIP 0.736
Web of Science (2015): Impact factor 1.606
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.92 SJR 0.644 SNIP 0.94
Web of Science (2014): Impact factor 1.735
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.18 SJR 0.747 SNIP 1.027
Web of Science (2013): Impact factor 1.687
Enhancement of the Direct Sulfitation of Limestone by Alkali Metal Salts, Calcium Chloride, and Hydrogen Chloride

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, The Aerosol Laboratory
Contributors: Hu, G., Dam-Johansen, K., Wedel, S.
Pages: 5295-5303
Publication date: 2007
Peer-reviewed: Yes

Publication information
Journal: Industrial & Engineering Chemistry Research
Enzyme-based Antifouling Coatings

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Publication date: 2007

Host publication information
Title of host publication: Book of Abstracts
Source: orbit
Source-ID: 211027
Research output: Research - peer-review • Article in proceedings – Annual report year: 2007

Enzyme-based antifouling coatings: a review
A systematic overview is presented of the literature that reports the antifouling (AF) protection of underwater structures via the action of enzymes. The overall aim of this review is to assess the state of the art of enzymatic AF technology, and to highlight the obstacles that have to be overcome for successful development of enzymatic AF coatings. The approaches described in the literature are divided into direct and indirect enzymatic AF, depending on the intended action of the enzymes. Direct antifouling is used when the enzymes themselves are active antifoulants. Indirect antifouling refers to the use of enzymes to release an active biocide with AF activity. For direct AF, several patents have been granted, and a commercial product has been launched. However, the achievement of an efficient broad-spectrum AF coating based on a single or a few enzymes has not yet been achieved. An indirect AF coating is not yet available commercially. The technology is mainly limited by the instability of substrate supply, whether the substrates are found in the surrounding seawater or in the coating itself. Legislative issues regarding which part(s) of an enzyme system should be regarded as biocidal for product registration purposes are also considered. The above question currently remains unanswered for technologies utilising indirect enzymatic AF.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Electromagnetic Systems, Department of Electrical Engineering
Pages: 369-383
Publication date: 2007
Peer-reviewed: Yes

Publication information
Journal: Biofouling
Volume: 23
Issue number: 5
ISSN (Print): 0892-7014
Ratings:
BFI (2019): BFI-level 2
Fly Ash and Adsorption of Air-Entraining Agents in Concrete: Influence of Combustion Conditions

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Pedersen, K. H., Jensen, A. D., Dam-Johansen, K.
Publication date: 2007

Host publication information
Title of host publication: Book of Abstracts
Source: orbit
Source-ID: 211016
Research output: Research - peer-review › Article in proceedings – Annual report year: 2007

Harvesting Straw Bio-Oil on the Field

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Publication date: 2007

Host publication information
Title of host publication: Book of Abstracts
Source: orbit
Source-ID: 211038
Research output: Research - peer-review › Article in proceedings – Annual report year: 2007

Kinetics of tyre char oxidation under combustion conditions

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, FLSmidth & Co. A/S
Pages: 2343-2350
Publication date: 2007
Peer-reviewed: Yes

Publication information
Journal: Fuel
Volume: 86
ISSN (Print): 0016-2361
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.4 SJR 1.891 SNIP 2.127
Web of Science (2017): Impact factor 4.908
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.9 SJR 1.736 SNIP 2.207
Web of Science (2016): Impact factor 4.601
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Product Development – What to Make and How to Make

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Ng, K. M., Gani, R., Dam-Johansen, K.
Pages: 473-489
Publication date: 2007

Host publication information
Title of host publication: Computer-Aided Chemical Engineering, 23
Source: orbit
Source-ID: 193710
Research output: Research - peer-review › Book chapter – Annual report year: 2007

Product inhibition of cellulases during enzymatic hydrolysis of the pre-treated ligno-cellulose

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Center for BioProcess Engineering
Publication date: 2007
Peer-reviewed: Yes
Event: Poster session presented at Book of Abstracts, European Congress of Chemical Engineering (ECCE-6),
Source: orbit
Source-ID: 210996
Research output: Research - peer-review › Poster – Annual report year: 2007

Quantification of glucose inhibition of enzymatic cellulose degradation in pre-treated wheat straw

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Center for BioProcess Engineering
Publication date: 2007

Host publication information
Title of host publication: Book of abstracts and oral presentation
Source: orbit
Source-ID: 210998
Research output: Research - peer-review › Article in proceedings – Annual report year: 2007

Release of Potentially Corrosive Constituents from the Grate of a Waste-to-Energy Boiler

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Babcock & Wilcox Vølund A/S
Contributors: Bøjer, M., Jensen, P. A., Frandsen, F., Dam-Johansen, K., Madsen, O. H., Lundtorp, K.
Pages: 1-17
Publication date: 2007

Host publication information
Title of host publication: IT3’07
Source: orbit
Source-ID: 219842
Research output: Research - peer-review › Article in proceedings – Annual report year: 2007

Replacement of the foam index test with surface tension measurements
Solid-state diffusion and crystal growth: two key steps for gas-solid reactions

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Hu, G., Dam-Johansen, K., Wedel, S.
Publication date: 2007

Host publication information
Title of host publication: Book of Abstracts
Source: orbit
Source-ID: 211022
Research output: Research - peer-review › Article in proceedings – Annual report year: 2007

Mathematical Modelling and Experimental Investigation of Full-scale Gypsum Producing Wet Flue Gas Desulphurisation

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Nygaard, H., Johnsson, J. E., Kiil, S., Dam-Johansen, K.
Number of pages: 128
Publication date: Feb 2006

Publication information
Original language: English
Source: orbit
Source-ID: 186353
Research output: Research › Ph.D. thesis – Annual report year: 2006

Accelerated Optimisation of Chemically-Active of Paint Products

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Yebra, D., Kiil, S., Weinell, C., Dam-Johansen, K.
Publication date: 2006
Antifouling Paint Containing Enzymes as Active Antifoulant

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Publication date: 2006
Peer-reviewed: No
Source: orbit
Source-ID: 195791
Research output: Research › Conference abstract for conference – Annual report year: 2006

Comments to "Analysis of constant rate period of spray drying of slurry" by Liang et al.
In the study by Liang et al. [2001. Analysis of constant rate period of spray drying of slurry. Chemical Engineering Science 56, 2205-2213] the Darcy flow of liquid through a pore system of primary particles to the surface of a slurry droplet was applied for the constant rate period. Steep primary particle concentration gradients inside -25 mu m droplets with a primary particle size of 0.2 mu m were observed. Unfortunately, the boundary condition at the droplet surface for the parabolic second-order PDE did not conserve the solid mass in the droplet, and the plots for the primary particle concentration profiles in the droplets were incorrect. In this letter we derive the correct boundary condition equation. Furthermore, we show that the primary particle concentration profiles inside the droplets are flat when the primary particles have a size of 0.2 mu m. We conclude that the model presented by Liang et al. is unable to predict the formation of hollow particles. (c) 2005 Elsevier Ltd. All rights reserved.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Jørgensen, K., Jensen, A., Sloth, J., Dam-Johansen, K., Bach, P.
Pages: 2096-2100
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 61
Issue number: 6
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.306
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
Web of Science (2016): Impact factor 2.895
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
Web of Science (2015): Impact factor 2.75
Web of Science (2015): Indexed yes
Decomposition and oxidation of pyrite
Devolatilization characteristics of large particles of tyre rubber under combustion conditions

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Energy Engineering, Department of Mechanical Engineering, Technical University of Denmark, FLSmidth & Co. A/S
Pages: 1335-1345
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: Fuel
Volume: 85
Issue number: 10-11
ISSN (Print): 0016-2361
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.4 SJR 1.891 SNIP 2.127
Web of Science (2017): Impact factor 4.908
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.9 SJR 1.736 SNIP 2.207
Web of Science (2016): Impact factor 4.601
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.46 SJR 1.781 SNIP 2.123
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 4.14 SJR 1.634 SNIP 2.294
Web of Science (2014): Impact factor 3.52
Web of Science (2014): Indexed yes
Dissolution rate measurements of sea water soluble pigments for antifouling paints: ZnO
The dissolution of soluble pigments from both tin-based and tin-free chemically active antifouling (AF) paints is a key process influencing their polishing and biocide leaching rates. In this context, a low time- and resources-consuming method capable of screening the pigment behaviour in the search for the most promising materials or mixtures is of great interest. A preliminary attempt to develop such a method is presented in this paper based on the widely used ZnO pigments.

While highly pure, nano-polished, monocrystalline ZnO substrates yielded very low dissolution rates in the order of 17.3 +/- 3.7 µg Zn2+ cm(-2) day(-1), pellets prepared by compacting and sintering technical grade ZnO pigments dissolved about three times faster according to inductively-coupled plasma mass spectrometry (ICP-MS) measurements. The rougher and more porous surface exposed, together with the larger number of defects in the lattice structure, are
hypothesised to be responsible for the faster sea water attack of the pellets compared to the ZnO crystals. In any case, the ZnO dissolution rates reported in this paper are markedly lower than those associated with the sea water dissolution of cuprous oxide (Cu2O) particles which are also used in AF paints. Experimental performance testing of model antifouling paints formulated with ZnO and/or Cu2O demonstrates that the binder/pigment interaction should not be disregarded if the leaching of sea water soluble pigments from paint systems is to be determined. (C) 2006 Elsevier B.V. All rights reserved.
Effect of Fed-Batch Loading of Substrate on Enzymatic Hydrolysis & Viscosity of Pretreated Barley Straw

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Rosgaard, L., Andric, P., Dam-Johansen, K., Pedersen, S., Meyer, A.
Publication date: 2006

Host publication information
Title of host publication: Biological Conversions and Processes for Renewable Feedstocks I
Source: orbit
Source-ID: 195809
Research output: Research - peer-review › Article in proceedings – Annual report year: 2006

Effect of Solvents on the Product Distribution and Reaction Rate of a Buchwald-Hartwig Amination Reaction
The Buchwald-Hartwig amination reaction between p-bromotoluene and piperazine in the presence of the homogeneous catalytic system Pd(dba)2/(+/-)-BINAP and the base NaO-t-Bu was investigated in two different classes of solvents: aprotic, nonpolar and aprotic, polar. The reaction was carried out using microwaves as the heating source, and it was found that the product distribution was strongly dependent on the class of the solvent. Based on the experimental results the selectivity towards the desired monosubstituted aryl piperazine was calculated, and it was found that the most appropriate solvent for the Buchwald-Hartwig amination reaction under the conditions applied was m-xylene.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Christensen, H., Kiil, S., Dam-Johansen, K., Nielsen, O., Sommer, M.
Pages: 762-769
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: Organic Process Research and Development
Volume: 10
Issue number: 4  
ISSN (Print): 1083-6160  
Ratings:

BFI (2019): BFI-level 1  
Web of Science (2019): Indexed yes  
BFI (2018): BFI-level 1  
Web of Science (2018): Indexed yes  
BFI (2017): BFI-level 1  
Scopus rating (2017): CiteScore 2.95 SJR 1.405 SNIP 0.978  
Web of Science (2017): Impact factor 3.584  
Web of Science (2017): Indexed yes  
BFI (2016): BFI-level 1  
Scopus rating (2016): CiteScore 2.48 SJR 1.068 SNIP 0.85  
Web of Science (2016): Impact factor 2.857  
Web of Science (2016): Indexed yes  
BFI (2015): BFI-level 1  
Scopus rating (2015): CiteScore 2.54 SJR 1.301 SNIP 1.01  
Web of Science (2015): Impact factor 2.922  
Web of Science (2015): Indexed yes  
BFI (2014): BFI-level 1  
Scopus rating (2014): CiteScore 2.38 SJR 1.033 SNIP 0.982  
Web of Science (2014): Impact factor 2.528  
Web of Science (2014): Indexed yes  
BFI (2013): BFI-level 1  
Scopus rating (2013): CiteScore 2.44 SJR 1.135 SNIP 0.967  
Web of Science (2013): Impact factor 2.549  
ISI indexed (2013): ISI indexed yes  
Web of Science (2013): Indexed yes  
BFI (2012): BFI-level 1  
Scopus rating (2012): CiteScore 2.32 SJR 1.203 SNIP 1.128  
Web of Science (2012): Impact factor 2.739  
ISI indexed (2012): ISI indexed yes  
Web of Science (2012): Indexed yes  
BFI (2011): BFI-level 1  
Scopus rating (2011): CiteScore 2.22 SJR 1.213 SNIP 0.909  
Web of Science (2011): Impact factor 2.391  
ISI indexed (2011): ISI indexed yes  
Web of Science (2011): Indexed yes  
BFI (2010): BFI-level 1  
Scopus rating (2010): SJR 1.12 SNIP 0.965  
Web of Science (2010): Impact factor 2.207  
Web of Science (2010): Indexed yes  
BFI (2009): BFI-level 1  
Scopus rating (2009): SJR 1.063 SNIP 0.924  
BFI (2008): BFI-level 1  
Scopus rating (2008): SJR 0.955 SNIP 0.926  
Web of Science (2008): Indexed yes  
Scopus rating (2007): SJR 1.017 SNIP 0.944  
Web of Science (2007): Indexed yes  
Scopus rating (2006): SJR 1.093 SNIP 0.889  
Web of Science (2006): Indexed yes  
Scopus rating (2005): SJR 0.862 SNIP 0.817  
Scopus rating (2004): SJR 0.708 SNIP 0.797
Effects of marine microbial biofilms on the biocide release rate from antifouling paints – A model-based analysis

The antifouling (AF) paint model of Kiil et al. [S. Kiil, C.E. Weinell, M.S. Pedersen, K. Dam-Johansen, Analysis of self-polishing antifouling paints using rotary experiments and mathematical modelling, Ind. Eng. Chem. Res. 40 (2001) 3906-3920] and the simplified biofilm growth model of Gujer and Warmer [W. Gujer, O. Warmer, Modeling mixed population biofilms, in: W.G. Characklis, K.C. Marshall (Eds.), Biofilms, Wiley-Interscience, New York, 1990] are used to provide a reaction engineering-based insight to the effects of marine microbial slimes on biocide leaching and, to a minor extent, polishing behaviour of AF paints. It is concluded that the perturbation of the local sea water conditions (e.g. pH), as a consequence of the metabolic activity of the biofilm should not affect the net biocide leaching and binder reaction rates significantly. This results from the thin and poorly active biofilms which presumably grow onto the highly effective modern AF paints. According to simulations, the experimental decrease in the biocide leaching rate caused by biofilm growth must be mainly attributed to adsorption of the biocide by the exopolymeric substances secreted by the microorganisms. The effects of biofilms on the leaching of any generic active compound (e.g. natural antifoulants) are discussed in relation to their potential release mechanisms. The largest influence of biofilms is predicted for those active compounds that are released by a diffusion-controlled mechanism (typically tin-free algaeicides). (c) 2006 Elsevier B.V. All rights reserved.
Enzymes in Antifouling Coatings, a review

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Publication date: 2006
Peer-reviewed: No
Mathematical Modeling of Tin-Free Chemically-Active Antifouling Paint Behavior

Mathematical modeling has been used to characterize and validate the working mechanisms of tin-free, chemically-active antifouling (AF) paints. The model-based analysis of performance data from lab-scale rotary experiments has shown significant differences between antifouling technologies as regards the biocide leaching and the surface polishing processes. Hence, the modeling framework developed in this work is built so as to describe any generic, chemically-active AF paint through model parameters, the values of which can be obtained or adjusted from relatively fast measurements. The detailed quantitative information on reacting AF paint systems obtained can be used for accelerated product optimization purposes, thus facilitating the transition to cleaner antifouling technologies using, for example, fast-degrading natural or synthetic bioactive components. (c) 2006 American Institute of Chemical Engineers.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Hempel AS
Parametric Study of Tin-Free Antifouling Model Paint Behavior Using Rotary Experiments

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Hempel A/S
Contributors: Yebra, D. M., Kiil, S., Erik Weinell, C., Dam-Johansen, K.
Pages: 1636-1649
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: Industrial & Engineering Chemistry Research
Volume: 45
ISSN (Print): 0888-5885
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.4 SJR 0.978 SNIP 1.203
Web of Science (2017): Impact factor 3.141
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.1 SJR 0.95 SNIP 1.155
Web of Science (2016): Impact factor 2.843
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.87 SJR 0.938 SNIP 1.145
Web of Science (2015): Impact factor 2.567
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Presence and effects of marine microbial biofilms on biocide-based antifouling paints

Marine microorganisms are capable of successfully colonizing toxic surfaces through the formation of biofilm structures. In this article, most of the literature reporting the presence of marine biofilms on chemically-active antifouling paints is briefly reviewed. Of special concern is the influence of the dense extracellular polymeric substances (EPS) matrix on the release rate of the compounds involved in antifouling paint performance (i.e. active compounds and controlled-release binder...
molecules). A deeper understanding of these phenomena is of interest for both environmental legislators and paint formulators.

**General information**

State: Published  
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Hempel A/S  
Contributors: Yebra, D. M., Kiil, S., Erik Weinell, C., Dam-Johansen, K.  
Pages: 33-41  
Publication date: 2006  
Peer-reviewed: Yes

**Publication information**

Journal: Biofouling  
Volume: 22  
Issue number: 1  
ISSN (Print): 0892-7014  
Ratings:

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<td>2014</td>
<td>BFI-level 1</td>
<td>Indexed yes</td>
<td>Impact factor 3.96</td>
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<td>2013</td>
<td>BFI-level 1</td>
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<td>Impact factor 4.429</td>
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<td>2012</td>
<td>BFI-level 1</td>
<td>Indexed yes</td>
<td>Impact factor 5.333</td>
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<td>2011</td>
<td>BFI-level 1</td>
<td>Indexed yes</td>
<td>Impact factor 6.333</td>
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<td>Impact factor 7.333</td>
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<td>Indexed yes</td>
<td>Impact factor 8.333</td>
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<td>2008</td>
<td>BFI-level 1</td>
<td>Indexed yes</td>
<td>Impact factor 9.333</td>
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<td>Indexed yes</td>
<td>Impact factor 10.333</td>
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<td>BFI-level 1</td>
<td>Indexed yes</td>
<td>Impact factor 11.333</td>
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ISI indexed (2013): yes
Scopus rating (2007): SJR 0.869 SNIP 1.435
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.908 SNIP 1.14
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.693 SNIP 0.646
Scopus rating (2004): SJR 0.735 SNIP 0.969
Scopus rating (2003): SJR 0.56 SNIP 1.322
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.561 SNIP 0.731
Scopus rating (2001): SJR 0.519 SNIP 0.644
Scopus rating (2000): SJR 0.724 SNIP 1.126
Scopus rating (1999): SJR 0.663 SNIP 1.102
Original language: English
DOIs:
10.1080/08927010500519097
Source: orbit
Source-ID: 195179
Research output: Research - peer-review › Journal article – Annual report year: 2006

REtrol vision: Preliminary Techno-Economical Analysis

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Andric, P., Dam-Johansen, K., Jensen, P. A., Rosgaard, L.
Publication date: 2006
Peer-reviewed: No
Source: orbit
Source-ID: 195811
Research output: Research › Poster – Annual report year: 2006

REtrol vision: Preliminary Techno-Economical Analysis

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Computer Aided Process Engineering Center
Contributors: Andric, P., Dam-Johansen, K., Gani, R., Jensen, P. A.
Publication date: 2006

Host publication information
Title of host publication: Sustainable Power Systems
Source: orbit
Source-ID: 195810
Research output: Research - peer-review › Article in proceedings – Annual report year: 2006

Review of the direct sulfation reaction of limestone

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, The Aerosol Laboratory, FLSmidth & Co. A/S
Contributors: Hu, G., Dam-Johansen, K., Wedel, S., Hansen, J. P.
Pages: 386-407
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: Progress in Energy and Combustion Science
Volume: 32
Scale Up of Pharmaceutical Production of Organic Chemical Compounds

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Christensen, H., Kiil, S., Dam-Johansen, K., Nielsen, O., Sommer, M.
Publication date: 2006
Peer-reviewed: No
Source: orbit
Source-ID: 191826
Research output: Research - peer-review › Journal article – Annual report year: 2006

Studying the melting behavior of coal, biomass, and coal/biomass ash using viscosity and heated stage XRD data

The use of biomass for power generation can result in significant economical and environmental benefits. The greenhouse emissions can be reduced as well as the cost of the produced electricity. However, ash-related problems, including slagging, agglomeration, and corrosion, can cause frequent unscheduled shutdowns, decreasing the availability and increasing the cost of the produced power. In addition, the fouling of the heat exchange surfaces reduces the system efficiency. In this work the melting and rheological properties of various biomass and biomass/coal ash samples were studied by using a high-temperature rotational viscometer and a hot stage XRD. The produced data were used to calculate the operating temperature of a pilot-scale entrained flow reactor during the cocombustion of biomass/coal samples in order to ensure the slag flow and to avoid corrosion of the walls due to liquid slag/metal interaction. Biomass ash proved to have significantly different melting behavior compared to that of the coal ash. Furthermore, the addition of biomass to coal ash led to lower viscosity and subsequently to higher stickiness of the produced ash particles. The melting behavior of the slag generated by the cocombustion tests appeared to be somewhat different compared to that of the laboratory-prepared ash samples. The heated stage XRD data provide useful information regarding the reactions among the various ash compounds and the phase transformations during the heating and cooling of the ash samples and helped the explanation of the produced viscosity curves.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Arvelakis, S., Folkedahl, B., Dam-Johansen, K., Hurley, J.
Pages: 1329-1340
Publication date: 2006
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 20
Issue number: 3
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Alkali Induced Corrosion of Silicon Carbide Heating Elements in a High Temperature Furnace

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Arvelakis, S., Frandsen, F., Dam-Johansen, K.
Pages: 1-14
Publication date: 2005
Peer-reviewed: Yes

Publication information
Effect of formulation ingredients on drying kinetics and morphology of particles formed during spray drying

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Jørgensen, K., Jensen, A., Bach, P., Dam-Johansen, K.
Publication date: 2005

Host publication information
Title of host publication: 7th World Congress on Chemical Engineering
Source: orbit
Source-ID: 186379
Research output: Research - peer-review › Article in proceedings – Annual report year: 2005

Reaction rate estimation of controlled-release antifouling paint binders: Rosin-based systems
Biofouling on ship hulls is prevented by the use of antifouling (A/F) paints. Typically, sea water soluble rosin or rosin-derivatives are used as the primary means of adjusting the polishing rate of the current chemically active self-polishing paint systems to a suitable value. Previous studies have shown that mathematical coating models based on a fundamental knowledge of the underlying mechanisms of A/F paints is a promising tool for accelerated product testing at different operational conditions of a sailing ship or a paint rotor. Such models can also be used for generation of ideas aiming at product optimisation and innovation (e.g. incorporation of natural active agents). This study seeks to attain scientifically founded knowledge of the reaction mechanisms and the rate of reaction with sea water of a Zn-carboxylate of a synthetic rosin compound. The kinetic expression attained can be used as input to mathematical models describing the behaviour of rosin-containing tin-free A/F paints. The experimental procedures developed can be easily implemented by marine paint companies for the screening of novel controlled-release binder materials for A/F paints. As a first step, it is demonstrated that the degradation of this Zn-containing rosin-derivative by sea water plays a key role in the polishing mechanism of paints formulated with such a resin. Then, the relevant literature available on the sea water behaviour of rosin and rosin-based binders is reviewed. Subsequently, two experimental procedures for the reaction rate estimation of the selected rosin-derived resin are presented; one is based on a gravimetric approach while the other uses flame atomic absorption spectroscopy (FAAS) to determine the total Zn2+ released by the resin. Both methods yield well-defined reaction conditions and sufficiently high accuracies. The latter is important because very low steady state reaction rates (about 0.70 +/- 0.26 mg Zn(2+) cm(-2) day(-1) at 25 degrees C and pH 8.2) are measured. Steady state reaction rates of Cu2+ - and Mg2+ -derivatives are also determined and discussed. The experimental procedures developed are used to investigate the influence of NaCl concentration (12-52 g/l), pH (7.8-8.5) and sea water temperature (10-35 degrees C) on the rate of reaction of the Zn-carboxylate. Within that range of sea water conditions, the following kinetic expression is found to describe the steady state Zn2+ release rate resulting from the reaction of the Zn-carboxylate with sea water:

[GRAPHICS]
[GRAPHICS]
[GRAPHICS]
where the natural logarithm of the pre-exponential factor, \( \ln(A) \), is 18.0 +/- 2.5 (the unit of \( A \) being the same as \( k(1) \)), the activation energy, \( E_a \), is 18.5 +/- 6.0 kJ/mol and the reaction order with respect to the hydroxide ion concentration, \( a \), is 0.86 +/- 0.42. \( L-\text{znR} \) is the estimated solubility product of the \( \text{ZnR} \) resin which has a value of \( 3.1 \times 10^{-12} \text{ (mol/l)(-3)} \) (about 6 mg \( \text{Zn}^{2+} \)/l in equilibrium). The low value of the activation energy is believed to result from the complex reaction mechanisms hypothesised rather than pointing at a certain diffusion control in the reaction rate experiments. The reverse reaction is found not to affect the hydrolysis rate within the pores of antifouling paints significantly. It is concluded, from the reaction mechanism proposed, that the observed partial exchange of \( \text{Zn}^{2+} \) for \( \text{Cu}^{2+} \) in the resin structure during paint dispersion and immersion results in a lower reaction rate compared to the pure \( \text{ZnR} \). \( \text{Cu-carboxylate} \) has a reaction rate of about 5.8 +/- 1.0 \( \text{mg CuR cm}^{-2} \text{ day}^{-1} \) at 25 degrees C and pH 8.2. The presence of Mg and Na compounds (probably Mg- and Na-resinate) in the solid paint film has also been detected, and will influence the reaction rate by modifying the \( \text{ZnR} \) exposed surface area. 

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Secondary Capture of Chlorine and Sulfur during Thermal Conversion of Biomass

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Knudsen, J. N., Jensen, P. A., Lin, W., Dam-Johansen, K.
Pages: 606-617
Publication date: 2005
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 19
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Antifouling technology—past, present and future steps towards efficient and environmentally friendly antifouling coatings

The imminent ban of environmentally harmful tributyltin (TBT)-based paint products has been the cause of a major change in the antifouling paint industry. In the past decade, several tin-free products have reached the commercial market, and claimed their effectiveness as regards the prevention of marine biofouling on ships in an environmentally friendly manner. The main objective of this review is to describe these products in as much detail as possible based on the knowledge available in the open literature. This knowledge has been supplemented by means of performance data provided, upon request, by some of the paint-producing companies. An exhaustive review of the historical development of antifouling systems and a detailed characterisation of sea water are also included. The need for studies on the behaviour of chemically active paints under different sea water conditions is emphasised. In addition, the most common booster biocides used to replace TBT-containing compounds are listed and described. It must be stressed that there is still a lack
of knowledge of their potential environmental side effects.

The current interest in providing innovative antifouling technologies based on an improved understanding of the biological principles of the biofouling process is also considered in this review. From the analysis of the factors affecting the biofouling process, the interference with the settlement and attachment mechanisms is the most promising environmentally benign option. This can be accomplished in two main ways: imitation of the natural antifouling processes and modification of the characteristics of the substrate. The former mostly focuses on the study of the large amount of secondary metabolites secreted by many different marine organisms to control the fouling on their surfaces. The many obstacles that need to be overcome for the success of this research are analysed. The potential development of broad-spectrum efficient coatings based on natural antifoulants is far from commercialisation. However, exploitation of a weakening of biofouling adhesion by means of the non-stick and fouling-release concepts is at a rather advanced stage of development. The main advantages and drawbacks of these systems are presented along with a brief introduction to their scientific basis. Finally, other alternatives, which may eventually give rise to an efficient and environmentally benign antifouling system, are outlined. (C) 2003 Elsevier B.V. All rights reserved.
Scopus rating (2011): CiteScore 2.34 SJR 0.877 SNIP 1.598
Web of Science (2011): Impact factor 1.977
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.986 SNIP 1.513
Web of Science (2010): Impact factor 1.862
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.826 SNIP 1.332
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.837 SNIP 1.279
Scopus rating (2007): SJR 1.089 SNIP 1.371
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.243 SNIP 1.62
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.939 SNIP 1.15
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.706 SNIP 1.107
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.603 SNIP 1.48
Scopus rating (2002): SJR 1.368 SNIP 1.294
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.625 SNIP 1.031
Scopus rating (2000): SJR 0.784 SNIP 1.137
Scopus rating (1999): SJR 0.714 SNIP 1.128
Original language: English
Keywords: chemical product design, biofouling, antifouling paint, tin-free, biocides, fouling-release
DOIs:
10.1016/j.porgcoat.2003.06.001
Source: orbit
Source-ID: 116866
Research output: Research - peer-review › Review – Annual report year: 2004


General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Number of pages: 42
Publication date: 2004

Publication information
Place of publication: Kgs. Lyngby
Original language: English
Electronic versions:
NEI_DK_4636.pdf
Source: orbit
Source-ID: 116861
Research output: Research - peer-review › Report – Annual report year: 2004

Forskningscentret CHEC

General information
Full-scale measurements of SO2 gas phase concentrations and slurry compositions in a wet flue gas desulphurisation spray absorber

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Pages: 1151-1164
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Fuel
Volume: 83
Original language: English
URLs:
http://www.sciencedirect.com
Source: orbit
Source-ID: 41468
Research output: Research - peer-review → Journal article – Annual report year: 2004

Quantification of the release of Cl, K and S to the gas phase from combustion of annual biomass.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Knudson, J., Jensen, P. A., Dam-Johansen, K.
Pages: U1075-U1075
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Abstracts of Papers of the American Chemical Society
Volume: 227
ISSN (Print): 0065-7727
Ratings:
Web of Science (2019): Indexed yes
Web of Science (2018): Indexed yes
Web of Science (2017): Indexed yes
Scopus rating (2014): SJR 0.101 SNIP 0.013
Web of Science (2014): Indexed yes
Quantification of the Release of CL, K and S to the Gas Phase from Combustion of Annual Biomass

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Publication date: 2004

Host publication information
Title of host publication: Proceedings of the 2nd World Conference and Technology Exhibition on Biomass for Energy, Industry and Climate Protection, 10-14 May, Rome, Italy
Publisher: Energy Research Centre of the Netherlands (ECN)
Source: orbit
Source-ID: 41498
Research output: Research › Conference abstract in proceedings – Annual report year: 2004

SEM Investigation of Superheater Deposits from Biomass-Fired Boilers
Straw is used as fuel in relatively small-scale combined heat and power producing (CHP) grate boilers in Denmark. The large content of potassium and chlorine in straw greatly increases the deposit formation and corrosion of the superheater coils, compared to boilers firing coal. In this study, mature superheater deposit samples were extracted from two straw-fired boilers, Masnedø and Ensted, with fuel inputs of 33 MWth and 100 MWth, respectively. SEM (scanning electron microscopy) images and EDX (energy dispersive X-ray) analyses were performed on the deposit samples. Different strategies are adopted to minimize deposit problems at the two boilers. At Masnedø the final superheater steam temperature is 520 °C, no soot blowing of the superheaters is applied and a relatively large superheater area is used. At Ensted, an external wood-fired superheater is used in order to obtain a final steam temperature of 542 °C, while the steam exit temperature of the straw-fired boiler is 470 °C. The mature Masnedø deposit had a thickness of 2 to 15 centimeters and consisted of three distinct main layers. The thick intermediate layer was depleted in chlorine but rich in Si, K, and Ca. This Masnedø intermediate layer was probably generated by in-situ reaction between KCl and Si-rich ash particles, which leads to release of chlorine-containing gases. The innermost layer contained many sublayers of mainly iron oxide, KCl, and K2SO4. The Ensted deposit had a maximum thickness of a few centimeters. The intermediate Ensted layer consisted of melted KCl with inclusions of Ca- and Si-rich particles, and the innermost layer was an iron oxide next to a potassium sulfate layer. Compared to deposits formed on a...
probe during short-time experiments, the mature superheater deposits contained larger dense inner sublayers of pure KCl and K2SO4. The present study indicates that the innermost layer of the superheater deposits expands by condensation of KCl, even when the deposit has a thickness of several centimeters.

**General information**

State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Elsam A/S, Energi E2 A/S
Contributors: Jensen, P. A., Frandsen, F., Hansen, J., Dam-Johansen, K., Henriksen, N., Hørlyck, S.
Publication date: 2004
Peer-reviewed: Yes

**Publication information**

Journal: Energy & Fuels
Volume: 18
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Impact factor 2.79
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.52
Web of Science (2013): Impact factor 2.733
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.25
Web of Science (2012): Impact factor 2.853
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 3.05
Web of Science (2011): Impact factor 2.721
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Web of Science (2010): Impact factor 2.444
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Simultaneous Thermal Analysis (STA) on Ash from High-Alkali Biomass

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Arvelakis, S., Jensen, P. A., Dam-Johansen, K.
Pages: 1066-1076
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 18
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Impact factor 2.79
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.52
Web of Science (2013): Impact factor 2.733
Sulfur Transformations during Thermal Conversion of Herbaceous Biomass

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Knudsen, J. N., Jensen, P. A., Lin, W., Frandsen, F., Dam-Johansen, K.
Pages: 810-819
Publication date: 2004
Peer-reviewed: Yes

Publication Information
Journal: Energy & Fuels
Volume: 18
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
The Joint Project – Straw Combustion on a Grate, Physical, Chemical and Reaction Kinetic Data for Grate Modeling

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Department of Mechanical Engineering
Number of pages: 150
Transformation and Release to the Gas Phase of Cl, K, and S during Combustion of Annual Biomass

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Pages: 1385-1399
Publication date: 2004
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 18
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Impact factor 2.79
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.52
Web of Science (2013): Impact factor 2.733
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.25
Web of Science (2012): Impact factor 2.853
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 3.05
Web of Science (2011): Impact factor 2.721
ISI indexed (2011): ISI indexed yes
Activation Energy Distribution of Thermal Annealing of a Bituminous Coal

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Feng, B., Jensen, A., Bhatia, V. K., Dam-Johansen, K.
Pages: 399-404
Publication date: 2003
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 17
Issue number: 0
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Impact factor 2.79
Agglomeration in bio-fuel fired fluidized bed combustors

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Lin, W., Dam-Johansen, K., Frandsen, F.
Pages: 171-185
Publication date: 2003
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Journal
Volume: 96
Issue number: 0
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
An experimental study of biomass ignition

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Grotkjær, T., Dam-Johansen, K., Jensen, A., Glarborg, P.
Pages: 825-833
Publication date: 2003
Peer-reviewed: Yes
Ash and Deposit Formation in the Biomass Co-Fired Masnedø Combined Heat and Power Production Plant

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Pages: 1-17
Publication date: 2003
Peer-reviewed: Yes

Publication information
Journal: IFRF Combustion Journal
Issue number: 0
ISSN (Print): 1562-479X
Ratings:
Scopus rating (2017): CiteScore 0.25 SJR 0.103 SNIP 0.488
Scopus rating (2016): CiteScore 0 SJR 0.103 SNIP 0
Scopus rating (2015): CiteScore 0.12 SJR 0.136 SNIP 0.044
Scopus rating (2014): CiteScore 0 SJR 0.147 SNIP 0.278
Scopus rating (2013): CiteScore 0 SJR 0.104 SNIP 0
Scopus rating (2012): CiteScore 0.17 SJR 0.14 SNIP 0.183
Scopus rating (2011): CiteScore 0.22 SJR 0.118 SNIP 0.139
Scopus rating (2010): SJR 0.102 SNIP 0.5
Scopus rating (2009): SJR 0.113 SNIP 0
Scopus rating (2008): SJR 0.104 SNIP 0

Chemical Product Design - A new multidisciplinary teaching and research activity at Institut for Kemiteknik

General information
State: Published
Organisations: CERE – Center for Energy Resources Engineering, Department of Chemical and Biochemical Engineering, CHEC Research Centre, Computer Aided Process Engineering Center
Contributors: Kontogeorgis, G., Kiil, S., Abildskov, J., Johannessen, T., Dam-Johansen, K.
Publication date: 2003

Host publication information
Combustion of Biomass in Fluidized Beds—Problems and Some Solutions Based on Danish Experiences

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Lin, W., Johnsson, J. E., Jensen, A., Dam-Johansen, K.
Publication date: 2003

Host publication information
Title of host publication: Proceedings of FBC17
Source: orbit
Source-ID: 135851
Research output: Research - peer-review › Article in proceedings – Annual report year: 2003

Controlled drug delivery from swellable hydroxypropylmethylcellulose matrices: model-based analysis of observed radial front movements

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Kiil, S., Dam-Johansen, K.
Pages: 1-21
Publication date: 2003
Peer-reviewed: Yes

Publication information
Journal: Journal of controlled release
Volume: 90
Issue number: 0
Original language: English
URLs:
http://www.sciencedirect.com
Source: orbit
Source-ID: 41126
Research output: Research - peer-review › Journal article – Annual report year: 2003

Decomposition and Oxidation of Pyrite in a Fixed-Bed Reactor

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Pages: 4290-4295
Publication date: 2003
Peer-reviewed: Yes

Publication information
Journal: Industrial & Engineering Chemistry Research
Volume: 42
Issue number: 19
ISSN (Print): 0888-5885
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Determining the Melting Behaviour of Ashes from Incineration Plants via Thermal Analysis

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Arvelakis, S., Frandsen, F., Dam-Johansen, K.
Pages: 1005-1017
Publication date: 2003
Peer-reviewed: Yes

Publication information
Journal: Journal of Thermal Analysis and Calorimetry
Volume: 72
Issue number: 0
Original language: English
Source: orbit
Source-ID: 41160
Research output: Research - peer-review > Journal article – Annual report year: 2003

Estimation of Polishing and Leaching Behaviour of Antifouling Paints Using Mathematical Modelling: a Literature Review

The development of chemically active antifouling paints has traditionally been based on an empirical approach. Optimisation and evaluation of novel and existing products are frequently conducted by means of, for example, systematic paint rotary tests in the laboratory or at sea sites. In this review, the usefulness of combining rotary experiments with the development of detailed mathematical models of paint behaviour will be discussed with reference to the relevant literature. Mathematical models can generally be used in the design of suitable release systems for various active components such as proteins or biocides, as well as for the estimation of release rates from different compositions of paints under various seawater conditions. Insoluble matrix, soluble matrix and self-polishing paints will be considered. Simulations from recent publications that show the effects of dynamic changes in seawater on paint behaviour will be presented. Examples of potential uses of paint models for accelerated polishing and leaching tests and screening of novel paint components will also be discussed. Directions of future modelling work are suggested.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Kiil, S., Dam-Johansen, K., Erik Weinell, C., Pedersen, M. S., Codolar, S. A.
Pages: 37-43
Publication date: 2003
Peer-reviewed: Yes

Publication information
Journal: Biofouling
Volume: 19
ISSN (Print): 0892-7014
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.05 SJR 0.835 SNIP 1.069
Web of Science (2017): Impact factor 2.786
Web of Science (2017): Indexed yes
Modelling of in-line low-NOx calciners-NOx emission

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Oxidation of formaldehyde and its interaction with nitric oxide in a flow reactor

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Glarborg, P., Alzueta, M., Kjærgaard, K., Dam-Johansen, K.
Pages: 629-638
Publication date: 2003
Peer-reviewed: Yes

Publication information
Journal: Combustion and Flame
Volume: 132
Issue number: 4
ISSN (Print): 0010-2180
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.41 SJR 1.117 SNIP 2.184
Web of Science (2016): Impact factor 3.663
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 5.12 SJR 2.807 SNIP 2.379
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.78 SJR 1.335 SNIP 2.34
Web of Science (2014): Impact factor 3.082
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.85 SJR 2.722 SNIP 2.572
Web of Science (2013): Impact factor 3.708
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 4.12 SJR 1.361 SNIP 2.797
Web of Science (2012): Impact factor 3.599
ISI indexed (2012): ISI indexed yes
Deposit Formation and Corrosion in the Air Pre-heater of a Straw-fired Combined Heat and Power Production Boiler

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Pages: 1-23
Publication date: 2002
Peer-reviewed: Yes

Publication information
Journal: IFRF Combustion Journal
Volume: 0
Issue number: 200204
Original language: English
URLs:
Source: orbit
Source-ID: 41131
Research output: Research - peer-review › Journal article – Annual report year: 2003
Dynamic simulations of a self-polishing antifouling paint exposed to seawater

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Kiil, S., Dam-Johansen, K., Erik Weinell, C., Pedersen, M. S., Codolar, S. A.
Pages: 45-54
Publication date: 2002
Peer-reviewed: Yes

Publication information
Journal: Journal of Coating Technology
Volume: 74
Issue number: 929
Original language: English
Source: orbit
Source-ID: 40882
Research output: Research - peer-review > Journal article – Annual report year: 2002

Erratum: Dynamic simulations of a self-polishing antifouling paint exposed to seawater

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Kiil, S., Dam-Johansen, K., Codolar, S. A., Pedersen, M. S., Erik Weinell, C.
Number of pages: 3
Pages: 89-91
Publication date: 2002
Peer-reviewed: No

Publication information
Journal: Journal of Coatings Technology and Research
Volume: 74
Issue number: 932
ISSN (Print): 1547-0091
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.7 SJR 0.415 SNIP 0.894
Web of Science (2017): Impact factor 1.619
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.44 SJR 0.424 SNIP 0.658
Web of Science (2016): Impact factor 1.557
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.45 SJR 0.421 SNIP 0.794
Web of Science (2015): Impact factor 1.342
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.5 SJR 0.512 SNIP 1.045
Web of Science (2014): Impact factor 1.298
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 1.46 SJR 0.522 SNIP 0.981
Web of Science (2013): Impact factor 1.28
General information

State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Pages: 1065-1075
Publication date: 2002
Peer-reviewed: Yes

Publication information

Journal: Fuel
Volume: 81
Issue number: 8
Original language: English
Source: orbit
Source-ID: 40876
Research output: Research - peer-review Journal article – Annual report year: 2002

Mathematical modeling of an in-line low-NOx calciner

The reduction of the NOx content in in-line-calciner-type kiln systems can be made by optimization of the primary filing in the rotary kiln and of the secondary firing in the calciner. Because the optimization of calciner offers greater opportunities the mathematical modeling of this reactor is very important. A heterogeneous, dynamic mathematical model for an in-line low-NOx calciner based on non-isothermal diffusion reaction models for char combustion and limestone calcination has been developed. The importance of the rate at which preheated combustion air was mixed into the main flow was particularly studied. The results of the simulations indicate that the external heat and mass transfer to the char particles is not limiting. Internal diffusion of O2, CO, NO and CO2 is important especially in the reducing zone and the first pail of the oxidizing zone of the calciner and the internal heat transport limitation is significant for the endothermic limestone calcination. The rate at which preheated combustion air is mixed into the main flow directly influences the coal combustion rate, and thereby through the rate of heat release from combustion, it also influences the calcination rate and the temperature profile. The mixing rate has some influence on the CO concentration profile and an important influence on the overall degree of fuel-N to NO conversion. (C) 2002 Elsevier Science Ltd. All rights reserved.

General information
A fundamental mathematical model for a self-polishing antifouling paint was used to conduct a parameter study. The aims were to show how a mathematical model can reduce the amount of experimental work needed to estimate the behaviour of self-polishing antifouling paints at different conditions, and to suggest ways of controlling biocide release rates. A case study with an antifouling paint based on the well-known tributyltin self-polishing copolymer system showed that the rate of paint polishing was influenced, to various degrees, by the following parameters: seawater pH and concentration of NaCl, pigment particle size, pigment volume concentration of the paint, the rate of pigment dissolution, and the pore size distribution of the leached layer. The modelling approach can be applied to any type of self-polishing antifouling paint provided that kinetic, solubility and diffusivity data are available for the pertinent rate-influencing steps.
Scopus rating (2016): CiteScore 2.79 SJR 0.821 SNIP 1.348
Web of Science (2016): Impact factor 2.538
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.7 SJR 0.852 SNIP 1.434
Web of Science (2015): Impact factor 2.525
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.91 SJR 1.022 SNIP 1.671
Web of Science (2014): Impact factor 2.348
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.56 SJR 0.953 SNIP 1.673
Web of Science (2013): Impact factor 2.281
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.31 SJR 0.918 SNIP 1.611
Web of Science (2012): Impact factor 1.927
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 2.12 SJR 0.903 SNIP 1.327
Web of Science (2011): Impact factor 1.968
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.87 SNIP 1.32
Web of Science (2010): Impact factor 1.519
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.741 SNIP 1.018
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.646 SNIP 0.715
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.58 SNIP 0.773
Scopus rating (2006): SJR 0.648 SNIP 0.83
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.747 SNIP 1.05
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.651 SNIP 1.036
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.731 SNIP 0.733
Scopus rating (2002): SJR 0.926 SNIP 0.83
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 1.099 SNIP 1.026
Scopus rating (2000): SJR 1.02 SNIP 1.185
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 0.956 SNIP 1.205
Original language: English
DOIs:
10.1205/026387602753393358
Source: orbit
Source-ID: 40855
Modeling of in-line low-NOx calciners - a parametric study

Simulations with a heterogeneous model of an in-line low-NOx calciner, based on non-isothermal diffusion-reaction models for char combustion and limestone calcination combined with a kinetic model for NO formation and reduction, are reported. The analysis shows that the most important hydrodynamic parameter is the mixing rate of preheated combustion air into the sub-stoichiometric suspension leaving the reducing zone and the most important combustion parameter is the char reactivity. Also, the calcination rate modifies very much the temperature in the calciner, char and limestone conversion and NO emission. Carbon monoxide is a key component for the reduction of NO and reliable data for the kinetics of NO reduction by CO over CaO are very important for the prediction of the NO emission. The internal surface area of char and limestone particles influences the combustion and calcination rates and thereby the char and limestone conversion and the NO emission. (C) 2002 Elsevier Science Ltd. All rights reserved.
Seawater-Soluble Pigments and Their Potential Use in Self-Polishing Antifouling Paints: Simulation-based Screening Tool

This work concerns the on-going development of efficient and environmentally friendly antifouling paints for biofouling control on large ocean-going ships. It is illustrated how a detailed mathematical model for a self-polishing antifouling paint exposed to seawater can be used as a product engineering tool to obtain a quick estimate of the paint behaviour that a given seawater-soluble pigment will provide. In the present context, "pigment" refers to relevant particulate solids of organic-, inorganic-, or biological nature. Simulations performed at 15 and 30 degrees C suggest that pigment solubility and seawater diffusivity of dissolved pigment species have a significant influence on the polishing and leaching behaviour of a typical self-polishing paint system. The pigment size distribution, on the other hand, only has a minor influence on the paint-seawater interaction. Simulations also indicate that only compounds which are effective against biofouling at very low seawater concentrations are useful as active antifouling paint ingredients. The need for model verification and exploration of practical issues, subsequent a given pigment has been found of interest, is discussed. The model approach is of relevance in the search for novel antifouling paints and for the development of accelerated test methods. (C) 2002 Elsevier Science B.V. All rights reserved.
Analysis of Self-Polishing Antifouling Paints Using Rotary Experiments and Mathematical Modeling

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Kiil, S., Stanley, M., Dam-Johansen, K., Erik Weinell, C.
Pages: 3906-3920
Publication date: 2001
Peer-reviewed: Yes

Publication information
Journal: Industrial & Engineering Chemistry Research
Volume: 40
Issue number: 18
ISSN (Print): 0888-5885
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.4 SJR 0.978 SNIP 1.203
Web of Science (2017): Impact factor 3.141
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.1 SJR 0.95 SNIP 1.155
Web of Science (2016): Impact factor 2.843
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.87 SJR 0.938 SNIP 1.145
Web of Science (2015): Impact factor 2.567
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.85 SJR 1.009 SNIP 1.287
Web of Science (2014): Impact factor 2.587
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.6 SJR 0.975 SNIP 1.232
Web of Science (2013): Impact factor 2.235
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Bag House Filter Performance Studied by Numerical Simulations

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Frey, M., Jensen, A., Dam-Johansen, K., Rasmussen, S.
Pages: 3-12
Publication date: 2001
Peer-reviewed: Yes

Publication information
Journal: The transactions of the filtration society
Volume: 2
Chemical Product Engineering - A Cross-centre Activity at Institut for Kemiteknik

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Center for Phase Equilibria and Separation Processes, Computer Aided Process Engineering Center, The Aerosol Laboratory
Contributors: Kiil, S., Kontogeorgis, G. M., Abildskov, J., Vigild, M. E., Johannessen, T., Dam-Johansen, K.
Publication date: 2001
Peer-reviewed: No
Event: Abstract from Conference on Refocusing Chemical Engineering, Barga, Italy.

Chemical Product Engineering - A Cross-centre Activity at Institut for Kemiteknik

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Center for Phase Equilibria and Separation Processes, Computer Aided Process Engineering Center, The Danish Polymer Centre, The Aerosol Laboratory, Center for Energy Resources Engineering
Contributors: Kiil, S., Kontogeorgis, G., Abildskov, J., Vigild, M. E., Johannessen, T., Dam-Johansen, K.
Publication date: 2001
Peer-reviewed: No
Event: Poster session presented at Conference on Refocusing Chemical Engineering, Barga, Italy.

Coupling Thermal Deactivation with Oxidation for Predicting the Combustion of a Solid Fuel

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Zolin, A., Jensen, J., Dam-Johansen, K.
Pages: 1341-1360
Publication date: 2001
Peer-reviewed: Yes

Publication information
Journal: Combustion and Flame
Volume: 125
Issue number: 4
ISSN (Print): 0010-2180
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.27 SJR 2.427 SNIP 2.176
Web of Science (2017): Impact factor 4.494
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.41 SJR 1.117 SNIP 2.184
Web of Science (2016): Impact factor 3.663
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 5.12 SJR 2.807 SNIP 2.379
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.78 SJR 1.335 SNIP 2.34
Web of Science (2014): Impact factor 3.082
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.85 SJR 2.722 SNIP 2.572
Web of Science (2013): Impact factor 3.708
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 4.12 SJR 1.361 SNIP 2.797
Web of Science (2012): Impact factor 3.599
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 4.13 SJR 3.081 SNIP 2.747
Web of Science (2011): Impact factor 3.585
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.102 SNIP 2.499
Web of Science (2010): Impact factor 2.747
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.795 SNIP 2.287
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 0.903 SNIP 2.261
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 3.075 SNIP 2.427
Scopus rating (2006): SJR 1.953 SNIP 2.525
Scopus rating (2005): SJR 2.295 SNIP 2.284
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.001 SNIP 1.682
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.742 SNIP 1.91
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.951 SNIP 1.803
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 1.893 SNIP 1.931
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.854 SNIP 2.099
Scopus rating (1999): SJR 0.94 SNIP 1.629
Original language: English
Source: orbit
Source-ID: 58764
Research output: Research - peer-review › Journal article – Annual report year: 2001
Effect of Relative Humidity of Fabric Filter Performance

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Frey, M., Dam-Johansen, K., Rasmussen, S.
Publication date: 2001
Peer-reviewed: No
Source: orbit
Source-ID: 59696
Research output: Research › Conference abstract for conference – Annual report year: 2001

Effekte og miljøvenlige bundmalinger

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Kiil, S., Dam-Johansen, K.
Pages: 24-27
Publication date: 2001
Peer-reviewed: No

Publication information
Journal: Dansk Kemi
Volume: 82
Issue number: 12
ISSN (Print): 0011-6335
Original language: Danish
Source: orbit
Source-ID: 59000
Research output: Research › Journal article – Annual report year: 2001

Experimental Investigation of NO from Pulverized Char Combustion

NO formation and reduction during pulverized char combustion in the temperature range 850–1150°C have been investigated in fixed-bed combustion experiments. Chars from a high-volatile bituminous coal and an anthracite have been used. Under single-particle conditions the selectivity for NO formation from combustion of char from both fuel types lies in the range 65–100%. The NO formation selectivity under single-particle conditions was observed to be lowest at 850 °C, to have values close to 100% at 1050 and 1150 °C, and to be independent of O2 concentration. When conditions deviate from single-particle conditions, net NO formation is significantly lower due to NO reduction taking place simultaneously with NO formation. Rate expressions for NO reduction on char both in the presence and in the absence of O2 have been determined. For bituminous coal char, these rates are 10–100 times more rapid than values previously reported in literature, but are consistent with reburn-type experiments employing char as fuel. This discrepancy is mainly attributed to rapid char deactivation prior to measuring of NO reduction rates in previous determinations.

Shortly after pyrolysis, the effective NO-char reaction rate for pulverized bituminous coal char in the temperature range 850–1150 °C has been found to be given by

\[ r_{NO} = 6 \times 10^6 \text{m}^3\text{kgC}^{-1}\text{s}^{-1}\times e^{14800/T(\text{K})}\times [\text{charC}]\times [\text{NO}] \]

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Pages: 2271-2278
Publication date: 2001
Peer-reviewed: Yes
Formation of NO from Combustion of Volatiles from Municipal Solid Wastes

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Sørum, L., Skreiberg, Ø., Glarborg, P., Jensen, A. D., Dam-Johansen, K.
Pages: 195-212
Publication date: 2001
Peer-reviewed: Yes

Publication information
Journal: Combustion and Flame
Volume: 124
Issue number: 1-2
ISSN (Print): 0010-2180
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.27 SJR 2.427 SNIP 2.176
Web of Science (2017): Impact factor 4.494
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.41 SJR 1.117 SNIP 2.184
Web of Science (2016): Impact factor 3.663
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 5.12 SJR 2.807 SNIP 2.379
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.78 SJR 1.335 SNIP 2.34
Web of Science (2014): Impact factor 3.082
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.85 SJR 2.722 SNIP 2.572
Web of Science (2013): Impact factor 3.708
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 4.12 SJR 1.361 SNIP 2.797
Web of Science (2012): Impact factor 3.599
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 4.13 SJR 3.081 SNIP 2.747
Web of Science (2011): Impact factor 3.585
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes

BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.102 SNIP 2.499
Web of Science (2010): Impact factor 2.747
Web of Science (2010): Indexed yes

BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.795 SNIP 2.287
Web of Science (2009): Indexed yes

BFI (2008): BFI-level 2
Scopus rating (2008): SJR 0.903 SNIP 2.261
Web of Science (2008): Indexed yes

Scopus rating (2007): SJR 3.075 SNIP 2.427
Scopus rating (2006): SJR 1.953 SNIP 2.525
Scopus rating (2005): SJR 2.295 SNIP 2.284
Web of Science (2005): Indexed yes

Scopus rating (2004): SJR 1.001 SNIP 1.682
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.742 SNIP 1.91
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.951 SNIP 1.803
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 1.893 SNIP 1.931
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.854 SNIP 2.099
Scopus rating (1999): SJR 0.94 SNIP 1.629

Original language: English
Source: orbit
Source-ID: 51683
Research output: Research - peer-review › Journal article – Annual report year: 2001

HCl and SO2 Emissions from Full-Scale Biomass Fired Boilers

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Jensen, P. A., Frandsen, F., Dam-Johansen, K.
Publication date: 2001

Host publication information
Title of host publication: Proceedings
Source: orbit
Source-ID: 63970
Research output: Research › Article in proceedings – Annual report year: 2001

Influence of experimental protocol on activation energy in char gasification: the effect of thermal annealing

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Zolin, A., Jensen, A., Dam-Johansen, K., Jensen, L. S.
Pages: 1029-1032
Publication date: 2001
Peer-reviewed: Yes
Investigation of biomass pyrolysis by thermogravimetric analysis and differential scanning calorimetry: (special issue with selected papers of the 14th International Symposium on Analytical and Applied Pyrolysis, Sevilla, Spain, 2-6 April 2000)

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Stenseng, M., Jensen, A., Dam-Johansen, K.
Pages: 765-780
Publication date: 2001
Peer-reviewed: Yes

Publication Information
Journal: Journal of Analytical and Applied Pyrolysis
Volume: 58-59
ISSN (Print): 0165-2370
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.91 SJR 1.129 SNIP 1.312
Web of Science (2017): Impact factor 3.468
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 4.11 SJR 1.379 SNIP 1.572
Web of Science (2016): Impact factor 3.471
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 4.06 SJR 1.489 SNIP 1.635
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 4.08 SJR 1.691 SNIP 1.954
Web of Science (2014): Impact factor 3.564
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 3.6 SJR 1.036 SNIP 1.921
Web of Science (2013): Impact factor 3.07
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 3.26 SJR 1.408 SNIP 1.77
Web of Science (2012): Impact factor 2.56
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 3.07 SJR 1.388 SNIP 1.603
Web of Science (2011): Impact factor 2.487
ISI indexed (2011): ISI indexed yes
Investigation of Superheater Deposits From Two Straw Fired Boilers, Effects of Coal Quality on Power Plant Management: Ash Problems, Management and Solutions

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Jensen, P. A., Frandsen, F., Hansen, J., Skriver, A., Henriksen, N., Hörlyck, S., Dam-Johansen, K.
Publication date: 2001

Host publication information
Title of host publication: Proceedings
Source: orbit
Source-ID: 63984
Research output: Research › Article in proceedings – Annual report year: 2001

Kinetic Analysis of Char Thermal Deactivation
The thermal deactivation of several fuels was investigated by measuring the reactivity, of chars prepared in a thermogravimetric analyzer (TGA) apparatus at well-defined conditions in the temperature range 973-1673 K. Four coals, Blair Athol from Australia, Cerrejon from Colombia. Illinois no. 6 and demineralized Dietz from USA, and two alternative fuels, Danish leached straw and petroleum coke, were used in the experiments. The coal chars from demineralized Dietz, Illinois no. 6, and Cerrejon deactivate readily, whereas petroleum coke and Blair Athol show a relative high resistance to deactivation. Leached straw deactivated significantly, but maintains at any heat-treatment temperature a higher reactivity than the other chars. The inertinite-rich coal Blair Athol is more resistant to deactivation than two vitrinite-rich coals of the same ASTM rank, Cerrejon and Illinois no. 6. Cerrejon and Illinois no. 6 chars prepared in the TGA at 1673 K show a much lower reactivity than carbon extracts from boilers operated with these coals, possibly owing to enhanced annealing conditions in the TGA, such as low heating rates, relatively high temperatures, and long holding times.

Based on the char reactivity data for all chars obtained from the TGA, kinetic parameters in an annealing model reported in the literature were determined. A shifted Gamma distribution taking into account a positive activation energy at the beginning of deactivation, as well as a lower bound of char reactivity corresponding to the reactivity of a commercial graphite, provided the best fit to the experimental deactivation ratios. The annealing model predicts reasonably well the changes in reactivity of chars prepared in different reactor environments with much higher heating rates and temperatures than the TGA apparatus. This indicates that TGA experiments can be used to capture the reactivity differences of chars observed in combustion facilities.

General information
State: Published
Laboratory Investigation of the Release to Gas Phase of Potassium, Sulphur and Chlorine at Grate Combustion Conditions

Abstract

Low-Temperature Ash Deposit Formation and corrosion in Biomass-Fired Combined Heat and Power Production Boilers

Abstract

Pretreatment of straw for power production by pyrolysis and char wash

Publication information

Journal: Biomass & Energy
Removal of K and Cl by leaching of straw char

**General information**

State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Jensen, P. A., Sander, B., Dam-Johansen, K.
Pages: 447-457
Publication date: 2001
Peer-reviewed: Yes

**Publication information**

Journal: Biomass and Bioenergy
Volume: 20
Issue number: 6
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4 SJR 1.235 SNIP 1.436
Web of Science (2017): Impact factor 3.358
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.71 SJR 1.198 SNIP 1.385
Web of Science (2016): Impact factor 3.219
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.03 SJR 1.51 SNIP 1.596
Web of Science (2015): Impact factor 3.249
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 4.36 SJR 1.865 SNIP 1.964
Web of Science (2014): Impact factor 3.394
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.42 SJR 1.666 SNIP 1.811
Web of Science (2013): Impact factor 3.411
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.66 SJR 1.516 SNIP 1.754
Web of Science (2012): Impact factor 2.975
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 4.74 SJR 1.759 SNIP 2.296
Web of Science (2011): Impact factor 3.646
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Rheological properties of high-temperature melts of coal ashes and other silicates

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Becerra, S. V., Frandsen, F., Dam-Johansen, K.
Pages: 237-429
Publication date: 2001
Peer-reviewed: Yes

Publication information
Journal: Progress in Energy and Combustion Science
Volume: 27
ISSN (Print): 0360-1285
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 24.19 SJR 6.751 SNIP 9.626
Web of Science (2017): Impact factor 25.242
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 19.82 SJR 5.443 SNIP 9.119
Web of Science (2016): Impact factor 17.382
The Influence of Inorganic Materials on the Thermal Deactivation of Fuel Chars

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Pages: 1110-1122
Thermal Analysis and Kinetic Modelling of Wheat Straw Pyrolysis

**General information**
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Stenseng, M., Jensen, A., Dam-Johansen, K.
Pages: 1061-1075
Publication date: 2001

**Host publication information**
Title of host publication: Progress in thermochemical Biomass Conversion
Publisher: Blackwell Science Ltd
Edition: A.V. Bridgewater
Source: orbit
Source-ID: 59693
Research output: Research - peer-review › Article in proceedings – Annual report year: 2001

Thermal Analysis in Combustion Research

**General information**
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Stenseng, M., Zolin, A., Cenni, R., Frandsen, F., Jensen, A., Dam-Johansen, K.
Pages: 1325-1334
Publication date: 2001
Peer-reviewed: Yes

**Publication information**
Journal: Journal of Thermal Analysis and Calorimetry
Volume: 64
Issue number: 3
Original language: English
Source: orbit
Source-ID: 58755
Research output: Research - peer-review › Journal article – Annual report year: 2001

Timely detection of agglomeration in biomass fired fluidized beds

**General information**
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: van Ommen, J. R., Schouten, J. C., Coppens, M., Lin, W., Dam-Johansen, K., van den Bleek, C. M.
Publication date: 2001

**Host publication information**
Title of host publication: Timely detection of agglomeration in biomass fired fluidized beds
Volume: paper # 131
Source: orbit
Source-ID: 59697
Research output: Research - peer-review › Article in proceedings – Annual report year: 2001

Visualization methods in analysis of detailed chemical kinetics modelling

**General information**
State: Published
Deposit Formation in a 150 MWe Utility PF-Boiler during Co-combustion of Coal and Straw

A conventional pc-fired boiler at the Danish energy company I/S Midtkraft has been converted to coal-straw co-combustion, and a 2 year demonstration program was initiated in January 1996, addressing several aspects of coal-straw co-combustion. Deposition trials were performed as part of the demonstration program. A maximum straw share of approximately 20% (energy base) was used in the experiments. For the deposit samples collected, a visual analysis procedure was developed and each sample evaluated according to this. In addition, a number of samples were analyzed by scanning electron microscopy (SEM) combined with energy dispersive X-ray analyses (SEM-EDX) and bulk chemical analyses. In the visual analysis, a significant increase in the amount and tenacity of the upstream deposits was observed as a function of increased straw share, exposure time, and boiler load. The chemical analyses of the deposits show increased amounts of K and S during co-combustion, and the Fe-dominated upstream deposits formed during coal combustion are shifted toward more Ca- and Si-rich deposits during coal-straw co-combustion. However, the major part of K is observed to form K-Al silicates, which do not form problematic deposits. Go-firing straw also caused a change in the structure of the upstream deposits. During coal combustion an ordered, "finger" structure of the larger particles with small particles between was observed, whereas during co-combustion a more random deposition of the larger particles among the small ones was observed. No chlorine species was observed in the deposits collected, and selective chlorine corrosion is therefore not expected to constitute a problem in co-combustion of coal and straw up to 20% straw share, for the coal types utilized in the tests. However, deposition problems could arise when burning other coals, particularly coals with a high S or alkali metal content or a low content of ash. The behavior of K, Ca, S, and Cl was evaluated by use of thermodynamic calculations. The thermodynamically stable species agree with the observed behavior in the experiments, i.e. formation of stable K-Al silicate species as well as KxO4 is predicted. The calculations also emphasize that the mixing between the coal and straw species is essential for the deposition behavior, primarily by affecting the split between K-Al silicates and K2SO4.
Deposition of Potassium Salts on Heat Transfer Surfaces in Straw-Fired Boilers - A Pilot-Scale Study
**Emissions, Corrosion and Alkali Chemistry in Straw-Fired Combined Heat and Power Plants**

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Publication date: 2000

**Host publication information**
Title of host publication: Emissions, Corrosion and Alkali Chemistry in Straw-Fired Combined Heat and Power Plants
Source: orbit
Source-ID: 176861
Research output: Research - peer-review › Article in proceedings – Annual report year: 2000

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**Exhaust Oxidation of Unburned Hydrocarbons from Lean-Burn Natural Gas Engines**

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Kristensen, P. G., Karll, B., Bendtsen, A. B., Glarborg, P., Dam-Johansen, K.
Publication date: 2000

**Publication information**
Journal: Combustion Science and Technology
Volume: 157
Issue number: 1-6
ISSN (Print): 0010-2202
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.59 SJR 0.683 SNIP 0.88
Web of Science (2017): Impact factor 1.132
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.46 SJR 0.417 SNIP 1
Web of Science (2016): Impact factor 1.241
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.52 SJR 0.833 SNIP 0.976
Experimental and Kinetic Modeling Study of the Oxidation of Benzene

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Alzueta, M., Glarborg, P., Dam-Johansen, K.
Pages: 498-522
Publication date: 2000
Peer-reviewed: Yes

Publication information
Journal: International Journal of Chemical Kinetics
Volume: 32
Issue number: 8
ISSN (Print): 0538-8066
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.43 SJR 0.543 SNIP 0.755
Web of Science (2017): Impact factor 1.416
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.47 SJR 0.392 SNIP 0.797
Web of Science (2016): Impact factor 1.386
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.01 SJR 1.007 SNIP 0.988
Web of Science (2015): Impact factor 1.736
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.61 SJR 0.425 SNIP 0.985
Web of Science (2014): Impact factor 1.517
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 1.47 SJR 0.619 SNIP 0.91
Web of Science (2013): Impact factor 1.566
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 1.08 SJR 0.378 SNIP 0.733
Web of Science (2012): Impact factor 1.187
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 1.29 SJR 0.797 SNIP 0.8
Web of Science (2011): Impact factor 1.007
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.427 SNIP 0.944
Web of Science (2010): Impact factor 1.154
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.835 SNIP 0.985
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.446 SNIP 0.986
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.752 SNIP 0.929
Scopus rating (2006): SJR 0.567 SNIP 0.804
Scopus rating (2005): SJR 0.595 SNIP 1.028
Scopus rating (2004): SJR 0.568 SNIP 0.784
Scopus rating (2003): SJR 0.711 SNIP 0.966
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.671 SNIP 0.894
Scopus rating (2001): SJR 0.61 SNIP 1.173
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.514 SNIP 0.944
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 0.519 SNIP 0.804
Experimental Investigation of the Transformation and Release to Gas Phase of Potassium and Chlorine during Straw Pyrolysis

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Jensen, P. A., Frandsen, F., Dam-Johansen, K., Sander, B.
Pages: 1280-1285
Publication date: 2000
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 14
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Impact factor 2.79
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.52
Web of Science (2013): Impact factor 2.733
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.25
Web of Science (2012): Impact factor 2.853
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 3.05
Web of Science (2011): Impact factor 2.721
ISI indexed (2011): ISI indexed yes
Extending the fluidized bed monitoring method by using multiple references and multiple signals

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: van Ommen, J. R., Schouten, J. C., Coppens, M., Lin, W., Dam-Johansen, K., van den Bleek, C. M.
Publication date: 2000

Host publication information
Title of host publication: AIChE Annual Meeting
Volume: paper #6g
Source: orbit
Source-ID: 59698
Research output: Research - Article in proceedings – Annual report year: 2001

Grate Firing of Straw: Activities in the CHEC Research Centre

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Publication date: 2000

Host publication information
Title of host publication: Grate Firing of Straw: Activities in the CHEC Research Centre
Source: orbit
Source-ID: 176862
Research output: Research - Article in proceedings – Annual report year: 2000

Influence of Deposit Formation on Corrosion at a Straw Fired boiler
Straw-fired boilers generally experience severe problems with deposit formation and are expected to suffer from severe superheater corrosion at high steam temperatures due to the large alkali and chlorine content in straw. In this study, deposits collected (1) on air-cooled probes and (2) directly at the existing heat transfer surfaces of a straw-fired boiler have been examined. Deposits collected on air-cooled probes were found to consist of an inner layer of KCl and an outer layer of sintered fly ash. Ash deposits formed on the heat transfer surfaces all had a characteristic layered structure, with a dense layer of K2SO4 present adjacent to the metal surface. It is argued that the K2SO4 layer present adjacent to the metal surface may lead to reduced corrosion rates at this boiler. A discussion of the deposit structure, the K2SO4 layer formation mechanism, and the influence of the inner layer composition on the corrosion of the superheaters is provided.
Low Temperature Oxidation of Methane: The Influence of Nitrogen Oxides

An experimental investigation of methane oxidation in the presence of NO and NO2 has been made in an isothermal plug-flow reactor at 750-1250K. The temperature for on-set of oxidation was lowered by 250 K in the presence of NO or NO2 at residence times of 200 ms. At shorter residence times (140 ms) this enhancement effect is reduced for NO but maintained for NO2. Furthermore two temperature regimes of oxidation separated by an intermediate regime where only little oxidation takes place exist at residence times of 140 ms, if NO is the only nitrogen oxide initially present. The results were explained by the competition between three reaction paths from CH3 to CH2O. A direct high temperature path (A), a two-step NO2 enhanced low temperature path (B) and a slow three step NO enhanced path (C), which may produce NO2 to activate path B. The negative temperature coefficient behaviour was explained by a competition between paths (A) and (C). A previously published reaction set was modified to take these reaction patterns into account.
Modelling and Experiments of Straw Combustion in a Grate Furnace

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Pages: 199-208
Publication date: 2000
Peer-reviewed: Yes

Publication information
Journal: Biomass & Bioenergy
Volume: 19
Issue number: 3
ISSN (Print): 0961-9534
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4 SJR 1.235 SNIP 1.436
Web of Science (2017): Impact factor 3.358
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.71 SJR 1.198 SNIP 1.385
Web of Science (2016): Impact factor 3.219
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.03 SJR 1.51 SNIP 1.596
Web of Science (2015): Impact factor 3.249
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 4.36 SJR 1.865 SNIP 1.964
Web of Science (2014): Impact factor 3.394
Web of Science (2014): Indexed yes
Nitric Oxide Reduction by Non-hydrocarbon Fuels. Implications for Reburning with Gasification Gases

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Glarborg, P., Kristensen, P. G., Dam-Johansen, K., Alzueta, M., Millera, A., Bilbao, R.
Pages: 828-838
Publication date: 2000
Peer-reviewed: Yes

Publication information
Production of Heat and Power based on Agricultural Waste - Emission and Alkali Chemistry

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Dam-Johansen, K.
Publication date: 2000

Host publication information
Title of host publication: Production of Heat and Power based on Agricultural Waste - Emission and Alkali Chemistry
Source: orbit
Source-ID: 176859
Research output: Research - peer-review › Article in proceedings – Annual report year: 2000

The implications of chlorine-associated corrosion on the

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Nielsen, H. P., Frandsen, F., Dam-Johansen, K.
Pages: 283-298
Publication date: 2000
Peer-reviewed: Yes

Publication information
Journal: Progress in Energy and Combustion Science
Volume: 26
ISSN (Print): 0360-1285
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 24.19 SJR 6.751 SNIP 9.626
Web of Science (2017): Impact factor 25.242
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 19.82 SJR 5.443 SNIP 9.119
Web of Science (2016): Impact factor 17.382
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 21.6 SJR 8.077 SNIP 10.2
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 21.55 SJR 7.426 SNIP 11.879
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 22.43 SJR 8.259 SNIP 12.951
Web of Science (2013): Impact factor 16.909
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Deposition and High-Temperature Corrosion in Biomass-Fired Boilers

This thesis describes the fate of potassium, chlorine, and sulfur in regard to deposition and corrosion problems in straw-fired boilers. Full-scale deposition studies at Rudkøbing CHP, Kyndby Power Station and Masnedø CHP revealed that straw may form massive deposits in the convective pass of the boiler. Straw deposits consist of a white layer of potassium salts extending the whole circumference of the tube and an ellipse-shaped deposit on the windward side of the probe. The white layer is powdery and very easy to brush off. The main deposit on the windward side of the probe can be quite hard and difficult to remove and consist of impacted fly ash particles and large amounts of condensable salts which form a matrix which bonds the fly ash particles together. The fly ash particles in the deposit are dominated by potassium silicates and potassium-calcium-silicates. The deposition of potassium salts during straw combustion was studied in Sandia’s Multifuel Combustor. A layer of condensed potassium salts was found on the side of the deposition probes. The layer had a very characteristic dendritic structure which was made up of small individual particles. Vapor deposition phenomena were investigated with a newly developed condensation probe. SEM analyses revealed that the vapor deposits consisted of individual angular particles of primarily KCl (1-2 µm) and a sponge-like matrix of submicron particles consisting primarily of K2SO4, which may represent vapor condensate agglomerates. Potassium deposits mainly as potassium chloride in straw-fired boilers. If large amounts of sulfur are present in the system, the composition of the condensed potassium salts changes in favor of more potassium sulfate. This phenomenon was observed when straw was co-fired with oil at the Kyndby Power Station and when adding 500 ppmv SO2(g) to straw-combustion under high-temperature combustion conditions in the pilot-scale experiments at Sandia National Laboratories. The potassium sulfate found in these probe deposits is mainly believed to originate from deposition of gaseous potassium sulfate. This is based on a slow sulfation of KCl in the solid phase and that K2SO4 was deposited as clusters of K2SO4 aerosol particles which indicate the formation of gaseous potassium sulfate. With time the deposited potassium chloride may sulfate to form potassium sulfate due to thermodynamically driving forces, but potassium sulfate has only been detected in insignificant amounts in mature
deposits in straw-fired boilers formed over months of operation. The corrosion of superheater tubes is closely connected to the material which are deposited on the surface and deposits containing potassium chloride can cause severe high-temperature corrosion at elevated metal temperatures. Lab-scale corrosion experiments, where metal test elements were covered with synthetic potassium salts and real deposits and exposed to a simulated flue gas containing HCl(g) and SO2(g), provided information about the corrosion rate and corrosion mechanisms of boiler steel under conditions similar to straw-fired boilers. A characteristic layer of potassium sulfate and iron oxide was found adjacent to the metal oxide layers on all the metal test elements covered with a deposit containing KCl. The layer had a characteristic structure with iron oxide threads in the dense potassium sulfate matrix. The same characteristic feature was found in the inner deposit layer from the deposits collected at Rudkøbing and Masnede CHPs. In the probe deposits at Rudkøbing and Masnede CHPs, KCl was found in the inner deposit layer whereas K2SO4 was the component in the mature deposits at Masnede CHP. The density and morphology of these layers indicate that they have been molten. This was taken as evidence of a reaction between the deposit and the metal tube. A corrosion mechanism for chlorine corrosion is suggested. The mechanism is based on gaseous chlorine attack where iron and chromium in the metal react with gaseous chlorine forming volatile metal chlorides. The high partial pressure of chlorine close to the metal is believed to be caused by a rapid sulfation of KCl to K2SO4 in a melt formed adjacent to the metal surface. This mechanism can explain the shift in corrosion behavior with temperature which has been observed in full-scale corrosion tests.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Michelsen, H. P., Dam-Johansen, K.
Publication date: Mar 1999

Publication information
Place of publication: Kgs. Lyngby, Denmark
Publisher: Technical University of Denmark (DTU)
Original language: English
Source-ID: 276476
Research output: Research › Ph.D. thesis – Annual report year: 1999

Agglomeration in Fluidized Bed Combustion of Biomass - Mechanisms and Co-Firing with Coal

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Lin, W., Dam-Johansen, K.
Publication date: 1999

Host publication information
Title of host publication: Agglomeration in Fluidized Bed Combustion of Biomass - Mechanisms and Co-Firing with Coal
Source-ID: 174505
Research output: Research - peer-review › Article in proceedings – Annual report year: 1999

Analysis and Simulation of pilot scale engine experiments

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Bendtsen, A. B., Glarborg, P., Dam-Johansen, K.
Publication date: 1999

Publication information
Original language: English
Source-ID: 174515
Research output: Research - peer-review › Report – Annual report year: 1999

Characterization of Ashes and Deposits from High-Temperature Coal-Straw Co-Firing

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Åbo Akademi University
CHEC Annual Report

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Dam-Johansen, K.
Publication date: 1999

**Publication information**
Original language: English
Source: orbit
Source-ID: 174406
Research output: Research - peer-review › Journal article – Annual report year: 1999

Deposition and Corrosion in Straw- and Coal-straw Co-Fired Utility Boilers - Danish Experiences

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Rockwool International, Fynsværket, Elsam A/S, Elkraft Power Co Ltd.
Pages: 271-283
Publication date: 1999

**Host publication information**
Title of host publication: Impact of Mineral Impurities in Solid Fuel Combustion
Place of publication: New York
Publisher: Kluwer Academic/Plenum Publishers
Editor: et al., G.
ISBN (Print): 0-306-46126-9
DOIs: 10.1007/0-306-46920-0_20
Source: orbit
Source-ID: 176090
Research output: Research - peer-review › Article in proceedings – Annual report year: 1999

EFP 96, Final Report Journal No 1323/96-0007, Clean and Efficient Utilization of Biomass for Production of Electricity and Heat - Phase I in a Long-Term Strategic Research Project

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Frandsen, F., Jensen, P. A., Jensen, A., Lin, W., Johnsson, J. E., Michelsen, H. P., Andersen, K. H., Dam-Johansen, K.
Publication date: 1999

**Publication information**
Original language: English
Source: orbit
Source-ID: 174522
Equilibrium Characterization of Biofuel Thermal Conversion Processes

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Sørensen, M. A., Backman, R., Frandsen, F., Hansen, L. A., Dam-Johansen, K.
Publication date: 1999

Publication information
Original language: English
Source: orbit
Source-ID: 174592
Research output: Research - peer-review › Report – Annual report year: 1999

Executive Summary of Final Report for EFP-96 project on Clean and Efficient Utilization of Biomass for Production of Electricity and Heat: Phase 1 in a Long-Term Strategic Research Project

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Frandsen, F., Dam-Johansen, K.
Publication date: 1999

Publication information
Original language: English
Source: orbit
Source-ID: 176163
Research output: Research - peer-review › Report – Annual report year: 1999

Experimental Investigation and Kinetic Modelling of Biomass Pyrolysis

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Stenseng, M., Jensen, A., Dam-Johansen, K., Grønli, M.
Publication date: 1999

Host publication information
Title of host publication: Experimental Investigation and Kinetic Modelling of Biomass Pyrolysis
Source: orbit
Source-ID: 174512
Research output: Research - peer-review › Article in proceedings – Annual report year: 1999

Full Scale Deposition Trials at 150 MWe PF-boiler Co-firing COal and Straw: Summary of Results

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, I/S Midtkraft Energy Company
Contributors: Andersen, K. H., Frandsen, F., Hansen, P. F. B., Dam-Johansen, K.
Pages: 367-381
Publication date: 1999

Host publication information
Place of publication: New York
Publisher: Kluwer Academic/Plenum Publishers
Source: orbit
Source-ID: 166882
Research output: Research › Article in proceedings – Annual report year: 1999
Hydrodynamics of a commercial scale CFB boiler-study with radioactive tracer particles

This paper presents the experimental results with radioactive tracer particles in an 80 MWth circulating fluidized-bed boiler. Batches of gamma-ray emitting tracer particles were injected into the standpipe. The response curves of the impulse injection were measured by a set of successive scintillation detectors located at different parts of the boiler. The results show that there are significant differences of the response signals when boiler loading changes. A model has been developed to obtain information from the experimental data. The particle recirculating rate is obtained by fitting the model to the experimental data. In the same way, the average particle velocities in the furnace are estimated. The impact of loading on the particle recirculating rate and on the hydrodynamics of the boiler is discussed. (C) 1999 Elsevier Science Ltd. All rights reserved.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), I/S Midtkraft Energy Company, Hempel A/S
Contributors: Lin, W., Hansen, P. F., Dam-Johansen, K., Erik Weinell, C.
Number of pages: 12
Pages: 5495-5506
Publication date: 1999
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 54
Issue number: 20
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.306
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
Web of Science (2016): Impact factor 2.895
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
Web of Science (2015): Impact factor 2.75
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.81 SJR 1.104 SNIP 1.629
Web of Science (2014): Impact factor 2.337
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.95 SJR 1.145 SNIP 1.843
Web of Science (2013): Impact factor 2.613
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.77 SJR 1.172 SNIP 1.828
Web of Science (2012): Impact factor 2.386
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 2.8 SJR 1.19 SNIP 1.678
Hydrodynamics of a Commercial Scale CFB Boiler - Study with Radioactive Tracer Particles

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Hempel A/S, Rockwool International
Contributors: Lin, W., Weinell, C. E., Hansen, P. F., Dam-Johansen, K.
Publication date: 1999

Host publication information
Title of host publication: Hydrodynamics of a Commercial Scale CFB Boiler - Study with Radioactive Tracer Particles
Source: orbit
Source-ID: 174510
Research output: Research - peer-review › Article in proceedings – Annual report year: 1999

Lab-Scale Investigations of High-Temperature Corrosion

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Michelsen, H. P., Frandsen, F., Dam-Johansen, K.
Lab-Scale Investigations of High-Temperature Corrosion Phenomena in Straw-Fired Boilers

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Nielsen, H. P., Frandsen, F. J., Dam-Johansen, K.
Pages: 1114-1121
Publication date: 1999
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 13
Issue number: 6
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Impact factor 2.79
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.52
Web of Science (2013): Impact factor 2.733
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.25
Modelling of Limestone Dissolution in Wet FGD Systems

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Department of Applied Chemistry
Contributors: Kiil, S., Johnsson, J. E., Dam-Johansen, K.
Pages: 1-10
Publication date: 1999
Peer-reviewed: Yes

Publication information
Journal: Conference Proceedings for Power Plant Chemistry 1999
Volume: 1
Original language: English

Bibliographical note
CHEC paper 9924
Source: orbit
Source-ID: 176231
Research output: Research - peer-review › Journal article – Annual report year: 1999

Modelling of Limestone Dissolution in Wet FGD Systems: The Importance of an Accurate Particle Size Distribution

In wet flue gas desulphurisation (FGD) plants, the most common sorbent is limestone. Over the past 25 years, many attempts to model the transient dissolution of limestone particles in aqueous solutions have been performed, due to the importance for the development of reliable FGD simulation tools. In this work, a critical examination of the models was conducted. The survey revealed that the models rely on the use of adjustable parameters in order to match experimental data. To investigate this, a simple particle model was set up. Model predictions were compared to experimental data for three different Danish limestone types with very different particle size distributions (PSDs). All limestones were of a high purity. Model predictions were found to be qualitatively in good agreement with experimental data without any use of adjustable parameters. Deviations between measurements and simulations were attributed primarily to the PSD.
measurements of the limestone particles, which were used as model inputs. The PSDs, measured using a laser diffraction-based Malvern analyser, were probably not representative of the limestone samples because agglomeration phenomena took place when the particles were suspended in a liquid solution. The measured PSDs were sensitive to the addition of a dispersing agent, the dispersion time, and the presence of ultrasound. It was found that the different PSDs influenced the simulated rate of dis-solution significantly (i.e. from below to above the measured dissolution rate). The results of this work show that a representative PSD is essential in order to model the rate of dissolution of lime-stone particles accurately.
Quantification of fusion in ashes from solid fuel combustion
The fusion of ashes produced during solid fuel combustion greatly affects the tendency of these ashes to cause operational problems in utility boilers. In this paper, a new and quantitative laboratory method for assessing the fusion of ashes based on simultaneous thermal analysis, STA, is described. Using STA, melting is detected as an endothermic reaction involving no change in mass. The measurement signals are transferred into a fusion curve showing the melt fraction in the ash as a function of temperature. This is done either by a simple comparison of the energies used for melting in different temperature ranges or by accounting for the relevant melting enthalpies. The method repeatability is good, melting onset determinations and completions generally within 10 degrees C, and melt fractions at given temperatures generally within 10% melt. Results are presented for simple binary salt mixtures, for which the agreement with fusion as determined by phase diagrams is very good, and for straw (salt-rich) and coal (silicate-rich) ashes. Comparing ash fusion curves to index points of current standard ash fusion tests showed initial melting at temperatures typically between 50 degrees and 100 degrees C - but in extreme cases as low as 260 degrees C - below the melting onset as found by the standard fusion tests. Characterizing the fusion by STA provides a more detailed description of the ash fusion as compared to conventional methods, and the onset of ash fusion is more precisely determined. Furthermore, in combination with, e.g. computer-controlled scanning electron microscopy, the method enables identification of the chemical species melting in different temperature ranges. Since ash melting has a major impact on the deposit formation tendency, the presented detailed ash fusion determination improves the prediction of problems related to ash deposition in boilers. (C) 1999 Published by Elsevier Science B.V. All rights reserved.
Reduction and Decomposition N2O under CFBC Conditions

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Johnsson, J. E., Jensen, A., Nielsen, J. S., Dam-Johansen, K.
Publication date: 1999

Host publication information
Title of host publication: Reduction and Decomposition N2O under CFBC Conditions
Source: orbit
Source-ID: 175131
Research output: Research - peer-review › Journal article – Annual report year: 1999

Research output: Research - peer-review › Article in proceedings – Annual report year: 1999
Release of Potassium and Chlorine during Straw Pyrolysis

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Jensen, P. A., Dam-Johansen, K.
Publication date: 1999

Host publication information
Title of host publication: Release of Potassium and Chlorine during Straw Pyrolysis
Source: orbit
Source-ID: 174420
Research output: Research - peer-review › Article in proceedings – Annual report year: 1999

Research in Furnaces: Use and Test of On-line Equipment

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Lans, R. P. V. D., Hansen, J., Bank, L. H., Dam-Johansen, K.
Publication date: 1999

Host publication information
Title of host publication: Research in Furnaces: Use and Test of On-line Equipment
Source: orbit
Source-ID: 174483
Research output: Research - peer-review › Article in proceedings – Annual report year: 1999

Straw Combustion in Grate Furnaces

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Publication date: 1999

Host publication information
Title of host publication: Straw Combustion in Grate Furnaces
Source: orbit
Source-ID: 174715
Research output: Research - peer-review › Article in proceedings – Annual report year: 1999

Straw Combustion in Grate Furnaces

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Publication date: 1999

Host publication information
Title of host publication: Straw Combustion in Grate Furnaces
Source: orbit
Source-ID: 174714
Research output: Research - peer-review › Article in proceedings – Annual report year: 1999

Sulphur Capture by Alkali Content of Straw during Co-Firing with Coal in FBC

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Lin, W., Dam-Johansen, K.
A Chemical Engineering Model for Predicting NO Emissions and Burnout from Pulverized Coal Flames

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Technical University of Denmark, Doosan Babcock Ltd.
Contributors: Pedersen, L. S., Glarborg, P., Dam-Johansen, K., Hepburn, P., Hesselmann, G.
Pages: 251-314
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Combustion Science and Technology
Volume: 132
ISSN (Print): 0010-2202
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.59 SJR 0.683 SNIP 0.88
Web of Science (2017): Impact factor 1.132
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.46 SJR 0.417 SNIP 1
Web of Science (2016): Impact factor 1.241
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.52 SJR 0.833 SNIP 0.976
Web of Science (2015): Impact factor 1.193
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.19 SJR 0.461 SNIP 0.904
Web of Science (2014): Impact factor 0.991
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 1.15 SJR 0.616 SNIP 0.922
Web of Science (2013): Impact factor 0.976
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 1.2 SJR 0.446 SNIP 1.027
Web of Science (2012): Impact factor 1.011
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 1.41 SJR 0.932 SNIP 1.015
Web of Science (2011): Impact factor 0.857
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.513 SNIP 1.19
Web of Science (2010): Impact factor 1.105
Web of Science (2010): Indexed yes
A comparison of coal char reactivity determined from thermogravimetric and laminar flow reactor experiments

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, SK-Energy Europe Ltd., Elsam A/S
Contributors: Zolin, A., Jensen, A., Pedersen, L. S., Dam-Johansen, K., Tørslev, P.
Pages: 268-276
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 12
Issue number: 2
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.3
Web of Science (2014): Impact factor 2.79
A Model of the Coal Reburning Process

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Østberg, M., Glarborg, P., Johnsson, J. E., Pedersen, L. S., Dam-Johansen, K.
Pages: 3027-3035
Publication date: 1998

Host publication information
Title of host publication: Vol 27
Publisher: Combustion Institute
Source: orbit
Source-ID: 174412
Research output: Research - peer-review › Book chapter – Annual report year: 1998

Analytical Characterisation of Coal Ash: ELSAM-Idemitsu Kosan Cooperation Project.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Fynsværket
A Reduced Reaction Scheme for Volatile Nitrogen Conversion in Coal Combustion

In pulverised coal flames, the most important volatile nitrogen component forming NOx is HCN. To be able to model the nitrogen chemistry in coal flames it is necessary to have an adequate model for HCN oxidation. The present work was concerned with developing a model for HCN/NH3/NO conversion based on systematic reduction of a detailed chemical kinetic model. Models of different complexity were developed and tested under conditions similar to those in a pulverised coal flame. Comparisons of the models were made for ideal chemical reactors simulations (plug bow reactor and well-stirred reactor). Provided that the CO/H2 chemistry was described adequately, the reduced HCN/NH3/NO model compared very well with the detailed model over a wide range of stoichiometries. Decoupling of the HCN chemistry from the CO/H2 chemistry resulted in over-prediction of the HCN oxidation rate under fuel rich conditions, but had negligible effect on the CO/H2 chemistry. Comparison with simplified HCN models from the literature revealed significant differences, indicating that these models should be used cautiously in modelling volatile nitrogen conversion.
CHEC Annual Report, 1997

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Dam-Johansen, K.
Publication date: 1998

Publication information
Original language: English
Source: orbit
Source-ID: 168513
Chemometric Analysis of a Detailed Chemical Reaction for Methane Oxidation

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Bendtsen, A. B., Glarborg, P., Dam-Johansen, K.
Pages: 357-365
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Chemometrics and Intelligent Laboratory Systems
Volume: 44
ISSN (Print): 0169-7439
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 2.82 SJR 0.672 SNIP 1.222
Web of Science (2017): Impact factor 2.701
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.6 SJR 0.652 SNIP 1.213
Web of Science (2016): Impact factor 2.303
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.68 SJR 0.665 SNIP 1.258
Web of Science (2015): Impact factor 2.217
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.96 SJR 0.88 SNIP 1.762
Web of Science (2014): Impact factor 2.321
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.67 SJR 0.892 SNIP 1.43
Web of Science (2013): Impact factor 2.381
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.68 SJR 0.87 SNIP 1.627
Web of Science (2012): Impact factor 2.291
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 2.27 SJR 0.77 SNIP 1.323
Web of Science (2011): Impact factor 1.92
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 0.761 SNIP 1.152
Web of Science (2010): Impact factor 2.222
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.082 SNIP 1.314
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.96 SNIP 1.262
Web of Science (2008): Indexed yes
Co-firing straw and coal in a 150-MWe utility boiler: in situ measurements

A 2-year demonstration program is carried out by the Danish utility I/S Midtkraft at a 150-MWe PF-boiler unit reconstructed for co-firing straw and coal. As a part of the demonstration program, a comprehensive in situ measurement campaign was conducted during the spring of 1996 in collaboration with the Technical University of Denmark. Six sample positions have been established between the upper part of the furnace and the economizer. The campaign included in situ sampling of deposits on water/air-cooled probes, sampling of fly ash, flue gas and gas phase alkali metal compounds, and aerosols as well as temperature measurements. Material balance closures were carried out at all operating conditions. The experimental data was evaluated together with researchers from the Technical University of Denmark and the results were stored in a data base program developed under the CHEC-research program to predict deposition propensities and high temperature corrosion during co-combustion of straw and coal in PF-boilers. Danish full scale results from co-firing straw and coal, the test facility and test program, and the potential theoretical support from the Technical University of Denmark are presented in this paper. (C) 1998 Published by Elsevier Science B.V.
Deposition and high temperature corrosion in a 10 MW straw

Deposition and corrosion measurements were conducted at a 10 MW wheat straw fired stoker boiler used for combined power and heat production. The plant experiences major problems with deposits on the heat transfer surfaces, and test probes have shown enhanced corrosion due to selective corrosion for metal temperatures above 520 C. Deposition measurements carried out at a position equal to the secondary superheater showed deposits rich in potassium and chlorine and to a lesser extent in silicon, calcium, and sulfur. Potassium and chlorine make up 40-80 wt% of the deposits.
Mechanisms of deposit formation and selective corrosion are discussed based on the results of the practical measurements.

**General information**

State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Elsam A/S
Contributors: Michelsen, H. P., Frandsen, F., Dam-Johansen, K., Larsen, O. H.
Pages: 95-108
Publication date: 1998
Peer-reviewed: Yes

**Publication information**

Journal: Fuel Processing Technology
Volume: 54
Issue number: 1-3
ISSN (Print): 0378-3820
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.46 SJR 1.453 SNIP 1.729
Web of Science (2017): Impact factor 3.956
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.15 SJR 1.397 SNIP 1.729
Web of Science (2016): Impact factor 3.752
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.09 SJR 1.501 SNIP 1.817
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.96 SJR 1.612 SNIP 2.167
Web of Science (2014): Impact factor 3.352
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 3.83 SJR 1.61 SNIP 2.121
Web of Science (2013): Impact factor 3.019
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.77 SJR 1.644 SNIP 2.055
Web of Science (2012): Impact factor 2.816
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 3.38 SJR 1.544 SNIP 1.781
Web of Science (2011): Impact factor 2.945
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.599 SNIP 1.884
Web of Science (2010): Impact factor 2.781
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.531 SNIP 1.851
Experimental Investigation and Modelling of a Wet Flue Gas Desulphurisation Pilot Plant

A detailed model for a wet flue gas desulphurisation (FGD) pilot plant, based on the packed tower concept, has been developed. All important rate determining steps, absorption of SO2, oxidation of HSO3-, dissolution of limestone, and crystallisation of gypsum were included. Population balance equations, governing the description of particle size distributions of limestone in the plant, were derived. Model predictions were compared to experimental data such as gas phase concentration profiles of SO2, slurry pH-profiles, solids content of the slurry, liquid phase concentrations, and residual limestone in the gypsum. Simulations were found to match experimental data for the two limestone types investigated. A parameter study of the model was conducted with the purpose of validating assumptions and extracting information on wet FGD systems. The modelling tools developed may be applicable to other wet FGD plants.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Kiil, S., Michelsen, M. L., Dam-Johansen, K.
Pages: 2792-2806
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Industrial & Engineering Chemistry Research
Volume: 37
Issue number: 7
ISSN (Print): 0888-5885
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.4 SJR 0.978 SNIP 1.203
Web of Science (2017): Impact factor 3.141
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.1 SJR 0.95 SNIP 1.155
Web of Science (2016): Impact factor 2.843
Influence of Coal Quality on Combustion Performance

Three coals have been fired in a tangentially and an opposed fired full scale power plant (about 400 MWe) and in a pilot scale test rig (160 kWt) in order to investigate the influence of coal quality on nitrogen oxide (NO) formation and unburned carbon in relation to furnace design. In-flame and furnace gas temperatures have been measured, and substantial differences in temperature between the coals were observed in the full scale furnaces. Identical trends in NO emission as a function of coal type were obtained for the three furnaces. The emissions correlated well with the high temperature volatile yield obtained from heated wire mesh analysis. Under air staging conditions the pilot scale test rig was able to reproduce quantitatively the amount of NO from the tangentially fired plant, which operates with over fire air. This is probably due to the relatively small influence of the near burner mixing pattern on NO formation under these conditions. Emissions from the opposed fired plant with all combustion air introduced through the burners could only be qualitatively reproduced by the pilot furnace. Under single stage conditions the test rig provided higher NO levels. Carbon in ash levels did not show any correlation between the coals and the furnaces. An engineering, mathematical model has been developed describing radiation heat transfer and coal combustion in full scale furnaces. The model has been validated against measured temperatures and the amount of carbon in fly ash. The model was well able to predict average temperature and carbon in ash levels, but failed to predict the influence of coal quality on both temperature and carbon in ash. A brief parametric study has been performed on important model parameters.
ISSN (Print): 0016-2361
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.4 SJR 1.891 SNIP 2.127
Web of Science (2017): Impact factor 4.908
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.9 SJR 1.736 SNIP 2.207
Web of Science (2016): Impact factor 4.601
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.46 SJR 1.781 SNIP 2.123
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 4.14 SJR 1.634 SNIP 2.294
Web of Science (2014): Impact factor 3.52
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.31 SJR 1.762 SNIP 2.544
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.99 SJR 1.813 SNIP 2.425
Web of Science (2012): Impact factor 3.357
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 4.1 SJR 2.041 SNIP 2.423
Web of Science (2011): Impact factor 3.248
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.957 SNIP 2.298
Web of Science (2010): Impact factor 3.604
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.985 SNIP 2.27
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.613 SNIP 2.156
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.364 SNIP 1.86
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.229 SNIP 1.64
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.596 SNIP 1.73
Web of Science (2005): Indexed yes
Kinetic Modeling of Hydrocarbon/Nitric Oxide Interactions in a Flow Reactor

**General information**

State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, Sandia National Laboratories
Contributors: Glarborg, P., Alzueta, M., Dam-Johansen, K., Miller, J.
Pages: 1-27
Publication date: 1998
Peer-reviewed: Yes

**Publication information**

Journal: Combustion and Flame
Volume: 115
Issue number: 1-2
ISSN (Print): 0010-2180
Ratings:

BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.27 SJR 2.427 SNIP 2.176
Web of Science (2017): Impact factor 4.494
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.41 SJR 1.117 SNIP 2.184
Web of Science (2016): Impact factor 3.663
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 5.12 SJR 2.807 SNIP 2.379
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.78 SJR 1.335 SNIP 2.34
Web of Science (2014): Impact factor 3.082
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.85 SJR 2.722 SNIP 2.572
Web of Science (2013): Impact factor 3.708
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Low Temperature Gas Reburning. NOx Reduction Potential and Effects of Mixing.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering, University of Zaragoza
Contributors: Alzueta, M., Bilbao, R., Millera, A., Glarborg, P., Østberg, M., Dam-Johansen, K.
Pages: 329-338
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 12
Issue number: 2
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Mass transfer in wetted-wall columns: correlations at high Reynolds numbers

The rate of gas-and liquid-phase mass transport in a pilot-scale wetted-wall column with an inner diameter of 3.26 cm and a length of 5 m was investigated. Empirical correlations for the physical liquid-phase mass transfer coefficient \( k(L)(O) \) and the gas-phase mass transfer coefficient \( k(G) \) were determined. In dimensionless form, the correlations are given by

\[
Sh(L) = 0.01613 \text{ Re-G}^{0.664} \text{ Re-L}^{0.426} \text{ Sc-L}^{0.5}
\]

\[
Sh(G) = 0.00031 \text{ Re-G}^{1.05} \text{ Re-L}^{0.207} \text{ Sc-G}^{0.5}
\]

and are valid at gas-phase Reynolds numbers from 7500 to 18,300 and liquid-phase Reynolds numbers from 4000 to 12,000, conditions of industrial relevance. To our knowledge, no correlations for \( Sh(G) \) have been reported in the literature which are valid at such high Reynolds numbers. The wetted-wall column was equipped with six intermediate measuring positions for gas and two for liquid samples, giving rise to a high accuracy of the obtained correlations. Our data showed that \( Sh(L) \) and \( Sh(G) \) both depend on \( Re-G \) and \( Re-L \) due to changes in the interfacial area at the high Reynolds numbers employed. The presence of inert particles in the liquid-phase may influence the rate of mass transport, and experimental work was initiated to study the effect on \( k(G) \). A decrease in \( k(G) \) of up to 15% was seen at solid concentrations ranging from 0 to 30 wt%, though the observed effect could not be correlated. (C) 1997 Published by Elsevier Science Ltd.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, IBM, FLSmidth & Co. A/S
Contributors: Nielsen, C. H., Kiil, S., Thomsen, H. W., Dam-Johansen, K.
Pages: 495-503
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 53
Issue number: 3
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.306
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
Web of Science (2016): Impact factor 2.895
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
Web of Science (2015): Impact factor 2.75
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.81 SJR 1.104 SNIP 1.629
Web of Science (2014): Impact factor 2.337
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.95 SJR 1.145 SNIP 1.843
Web of Science (2013): Impact factor 2.613
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Possibilities and evaluation of straw pretreatment.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Nordjyllandværket A/S, Elsam A/S
Pages: 224-228
Publication date: 1998

Host publication information
Title of host publication: Biomass for Energy and Industry
Place of publication: Rimpar, Germany
Publisher: C.A.R.M.E.N.
Source: orbit
Source-ID: 170895
Pretreatment of Biofuels for Power Production.: 2nd annual progress report (1997)

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Elsam A/S
Contributors: Jensen, P. A., Sander, B., Dam-Johansen, K.
Number of pages: 10
Publication date: 1998

Publication information
Original language: English
Source: orbit
Source-ID: 170889
Research output: Research - peer-review › Report – Annual report year: 1998

Sintering in Biofuel and Coal-Biofuel Fired FBC's

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Lin, W., Dam-Johansen, K.
Publication date: 1998

Publication information
Original language: English
Source: orbit
Source-ID: 171034
Research output: Research - peer-review › Report – Annual report year: 1998

TG-FTIR Study of the Influence of potassium Chloride on Wheat Straw Pyrolysis

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Advanced Fuel Research Inc.
Contributors: Jensen, A., Dam-Johansen, K., Wójtowicz, M., Serio, M.
Pages: 929-938
Publication date: 1998
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 12
Issue number: 5
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
The Recombination of Hydrogen Atoms with Nitric Oxide at High temperatures

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, University of Zaragoza, Sandia National Laboratories
Contributors: Glarborg, P., Østberg, M., Alzueta, M., Dam-Johansen, K., Miller, J. A.
Pages: 219-226
Publication date: 1998

Host publication information
Title of host publication: Vol 27
Publisher: Combustion Institute
Source: orbit
Wet Flue Gas Desulphurisation and New Fuels

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Kiil, S., Dam-Johansen, K., Michelsen, M. L.
Number of pages: 115
Publication date: 1998

A comparative classification of char reactivity

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Avedøreværket, Elsam A/S
Pages: 991-994
Publication date: 1997

Agglomeration Phenomena in Fluidized Bed Combustion of Straw

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Lin, W., Krusholm, G., Dam-Johansen, K., Musahl, E., Bank, L. H.
Pages: 831-838
Publication date: 1997

Analytical Characterization of Coal Ashes - An Idemitsu Kosan-ELSAM Cooperation Project

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Fynsværket
Publication date: 1997
Catalytic and Gas-Solid Reactions Involving HCN over Limestone

In coal-fired combustion systems solid calcium species may be present as ash components or limestone added to the combustion chamber. In this study heterogeneous reactions involving HCN over seven different limestones were investigated in a laboratory fixed-bed quartz reactor at 873-1,173 K. Calcined limestone is an effective catalyst for oxidation of HCN. Under conditions with complete conversion of HCN at O-2 concentrations above about 5,000 ppmv the selectivity for formation of NO and N2O is 50-70% and below 5%, respectively. Nitric oxide can be reduced by HCN to N-2 in the absence of O-2 and to N-2 and N2O in the presence of O-2. At low O-2 concentrations or low temperatures. HCN may react with CaO, forming calcium cyanamide, CaCN2. The selectivities for formation of NO and N2O from oxidation of CaCN2 is 20-25% for both species. The catalytic activity of limestone for oxidation of HCN decreases with increasing degree of sulfation. Simultaneously the selectivity for formation of NO decreases while that for N2O increases. The catalytic activity of sulfated limestone increases with decreasing SO2 concentration indicating a competition between SO2 and HCN for sites on the surface. The results indicate that heterogeneous oxidation of HCN is important in calciners and fluidized-bed combustors with limestone addition or when burning coals with an ash with a high catalytic activity.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Jensen, A., Johnsson, J. E., Dam-Johansen, K.
Pages: 3070-3084
Publication date: 1997
Peer-reviewed: Yes

Publication information
Journal: A I Ch E Journal
Volume: 43
Issue number: 11
ISSN (Print): 0001-1541
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.31 SJR 1.015 SNIP 1.331
Web of Science (2017): Impact factor 3.326
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.11 SJR 1.035 SNIP 1.29
Web of Science (2016): Impact factor 2.836
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.03 SJR 1.085 SNIP 1.428
Web of Science (2015): Impact factor 2.98
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Characterization of microporous membranes for use in membrane contactors

General information
Chemical Reaction Conditions in a Danish 80 MWth CFB-Boiler Co-firing Straw and Coal

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Lin, W., Dam-Johansen, K.
Pages: 287-294
Publication date: 1997

Host publication information
Title of host publication: Proceedings of the 14th International Conference on Fluidized Bed Combustion
Place of publication: New York
Publisher: American Society of Mechanical Engineers
Source: orbit
Source-ID: 168229
Research output: Research - peer-review › Book chapter – Annual report year: 1997

Chemometric Analysis of a Detailed Chemical Reaction Mechanism for Methane Oxidation

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Bendtsen, A. B., Glarborg, P., Dam-Johansen, K.
Publication date: 1997

Host publication information
Title of host publication: Chemometric Analysis of a Detailed Chemical Reaction Mechanism for Methane Oxidation
Source: orbit
Source-ID: 176048
Research output: Research › Article in proceedings – Annual report year: 1997

Decomposition and reduction of N2O over Limestone under FBC Conditions

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Johnsson, J. E., Jensen, A., Vaaben, R., Dam-Johansen, K.
Pages: 953-966
Publication date: 1997
Decomposition and Reduction of N2O over Limestone under FBC Conditions

The addition of limestone for sulfur retention in fluidized bed combustion (FBC) has in many cases been observed to influence the emission of N2O. The catalytic activity of N2O over calcined Stevns Chalk for decomposition of N2O in a laboratory fixed bed quartz reactor was measured. It was found that calcined Stevns Chalk is an active catalyst for N2O decomposition in an inert atmosphere at FBC temperatures, and the presence of 3 vol% CO increased the rate of N2O destruction by a factor of 5 due to the catalytic reduction of N2O by CO. The activity decreased with increasing CO2 concentration, and uncalcined or recarbonated limestone had negligible activity. Sulfation of the calcined limestone under oxidizing conditions lowered the activity, however sulfidation under reducing conditions showed that CaS is an active catalyst for the reduction of N2O by CO. Without CO present a gas solid reaction between N2O and CaS takes place and SO2 is released.

Effects on SOx and NOx Emissions by Co-Firing Straw and Pulverized Coal

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Pedersen, L. S., Morgan, D., Kamp, W. V. D., Christensen, J., Jespersen, P., Dam-Johansen, K.
Page: 439-446
Publication date: 1997
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 11
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.34
Web of Science (2015): Impact factor 2.835
Electrodialysis with bipolar membranes for the manufacturing of low concentration acid and base

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, FLS Miljø A/S
Number of pages: 190
Publication date: 1997

Host publication information
Title of host publication: Proceedings 3rd International Symposium
Place of publication: Twente
Source: orbit
Source-ID: 174580
Research output: Research - peer-review › Journal article – Annual report year: 1997
Flow Pattern in a Fluidized Bed with a Non-fluidized Zone
The flow pattern of a fluidized bed with non-fluidized zones is investigated both experimentally and theoretically. Experiments were carried out in such a way that air was introduced only through part of the distributor. The results show a significant amount of air flowing to the zone where no air is introduced. However, once the gas velocity exceeds the minimum fluidization velocity in the zone where the air is introduced, the cross-flow hardly changes upon further increase of the gas velocity. A continuity equation and Ergun's equation are used to describe the flow pattern and pressure distribution over the bed. Very good agreement between the experimental and calculated results is achieved without any fitting parameter. The results are relevant to the understanding of heat transfer behaviour of a fluidized bed combustor (FBC) that is only partly fluidized to control its load.
Full scale deposition trials at 150 MWe PF-boiler co-firing coal and straw. Summary of results.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Rockwool International
Contributors: Andersen, K. H., Frandsen, F., Hansen, P. F., Dam-Johansen, K.
Publication date: 1997

Host publication information
Title of host publication: Full scale deposition trials at 150 MWe PF-boiler co-firing coal and straw. Summary of results.
Source: orbit
Source-ID: 175149
Research output: Research - peer-review › Article in proceedings – Annual report year: 1997

Gas-sensitive Properties and Structure of Nanostructured (a-Fe2O3)x-(SnO2)1-x Materials Prepared by Mechanical Alloying

General information
State: Published
Organisations: Department of Physics, Department of Chemical and Biochemical Engineering, Department of Chemistry, INM Institut für Neue Materialien
Contributors: Jiang, J., Lin, R., Lin, W., Nielsen, K., Mørup, S., Dam-Johansen, K., Clasen, R.
Pages: 1459-1467
Publication date: 1997
Peer-reviewed: Yes

Publication information
Volume: 30
ISSN (Print): 0022-3727
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.38 SJR 0.717 SNIP 1.011
Web of Science (2017): Impact factor 2.373
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.07 SJR 1.135 SNIP 1.122
Web of Science (2016): Impact factor 2.588
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.1 SJR 0.886 SNIP 1.25
Web of Science (2015): Impact factor 2.772
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.53 SJR 1.096 SNIP 1.408
Web of Science (2014): Impact factor 2.721
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.6 SJR 1.194 SNIP 1.452
Web of Science (2013): Impact factor 2.521
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
An experimental and theoretical investigation of mixing in the SNCR process was performed. The experiments were carried out in a bench scale reactor using the flue gas from a natural gas burner as the main gas and injection of a jet of NH3 mixed with carrier gas in crossflow. The results show a dependency on the carrier gas flow at temperatures above the optimum temperature for NO reduction. No dependency on the variation of the O2 concentration in the carrier gas from 0 to 21 vol% was observed. It was found that an increasing momentum ratio of the jet to the main gas improves the NO reduction up to a limiting value of the momentum ratio of approximately 20. Above this value no further improvement was observed. Chemical kinetic modelling of the initiating reactions involving NH3 showed that the reaction with OH radicals is the primary initiating reaction. It was also shown that process performance is influenced by the O2 concentration in the flue gas. The experimental results were used to verify the droplet diffusion model proposed by Ostberg and Dam-Johansen (1995, Chem. Engng Sci. 50, 2061-2067), using an empirical kinetic model valid for 4 vol% O2 in the reacting gas. (C) 1997 Elsevier Science Ltd.
Influence of Process Parameters on Nitrogen Oxide Formation in

This paper describes the influence of burner operating conditions, burner geometry and fuel parameters on the formation of nitrogen oxide during combustion of pulverized coal. Main attention has been paid to combustion test facilities with self-sustaining flames, while extensions have been made to full scale boilers and furnace modeling. Since coal combustion and flame aerodynamics have been reviewed earlier, these phenomena are only treated briefly.

General information

State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre
Contributors: Lans, R. P. V. D., Glarborg, P., Dam-Johansen, K.
Pages: 349-377
Publication date: 1997
Peer-reviewed: Yes

Publication information

Journal: Progress in Energy and Combustion Science
Volume: 23
Issue number: 4
ISSN (Print): 0360-1285
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 24.19 SJR 6.751 SNIP 9.626
Web of Science (2017): Impact factor 25.242
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 19.82 SJR 5.443 SNIP 9.119
Web of Science (2016): Impact factor 17.382
BFI (2015): BFI-level 2
Kemingeniøruddannelsen ved Institut for Kemiteknik, DTU

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Dam-Johansen, K.
Publication date: 1997
Kinetic NOx Modelling and Experimental Results from Single Wood Particle Combustion

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Norwegian University of Science and Technology
Contributors: Skreiberg, Ø., Glarborg, P., Jensen, A., Dam-Johansen, K.
Pages: 671-682
Publication date: 1997
Peer-reviewed: Yes

Publication information
Journal: Fuel
Volume: 76
Issue number: 7
ISSN (Print): 0016-2361
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.4 SJR 1.891 SNIP 2.127
Web of Science (2017): Impact factor 4.908
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.9 SJR 1.736 SNIP 2.207
Web of Science (2016): Impact factor 4.601
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.46 SJR 1.781 SNIP 2.123
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 4.14 SJR 1.634 SNIP 2.294
Web of Science (2014): Impact factor 3.52
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.31 SJR 1.762 SNIP 2.544
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.99 SJR 1.813 SNIP 2.425
Web of Science (2012): Impact factor 3.357
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 4.1 SJR 2.041 SNIP 2.423
Web of Science (2011): Impact factor 3.248
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Laboratory Study of the CO/NH3/NO/O2 System: Implications for Hybrid Reburn/SNCR Strategies

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Alzueta, M., Rejel, H., Kristensen, P. G., Glarborg, P., Dam-Johansen, K.
Pages: 716-723
Publication date: 1997
Peer-reviewed: Yes

Publication information
Journal: Energy & Fuels
Volume: 11
Issue number: 3
ISSN (Print): 0887-0624
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.55
Web of Science (2017): Impact factor 3.024
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.49
Web of Science (2016): Impact factor 3.091
Low Temperature Gas Reburning: NOx Reduction Potential and Effects of Mixing

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, University of Zaragoza
Contributors: Glarborg, P., Østberg, M., Dam-Johansen, K., Alzueta, M., Bilbao, R., Millera, A.
Publication date: 1997

Host publication information
Title of host publication: Low Temperature Gas Reburning
Low Temperature Interactions between Hydrocarbons and Nitric Oxide: An Experimental Study.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Alzueta, M., Glarborg, P., Dam-Johansen, K.
Pages: 25-36
Publication date: 1997
Peer-reviewed: Yes

Publication information
Journal: Combustion and Flame
Volume: 109
Issue number: 1-2
ISSN (Print): 0010-2180
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.27 SJR 2.427 SNIP 2.176
Web of Science (2017): Impact factor 4.494
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.41 SJR 1.117 SNIP 2.184
Web of Science (2016): Impact factor 3.663
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 5.12 SJR 2.807 SNIP 2.379
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 3.78 SJR 1.335 SNIP 2.34
Web of Science (2014): Impact factor 3.082
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.85 SJR 2.722 SNIP 2.572
Web of Science (2013): Impact factor 3.708
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 4.12 SJR 1.361 SNIP 2.797
Web of Science (2012): Impact factor 3.599
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 4.13 SJR 3.081 SNIP 2.747
Web of Science (2011): Impact factor 3.585
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.102 SNIP 2.499
Modelling of Devolatilization in Fluidized Bed Combustion

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Stenseng, M., Lin, W., Johnsson, J. E., Dam-Johansen, K.
Pages: 117-124
Publication date: 1997

Host publication information
Title of host publication: Proceedings of the 14th International Conference on Fluidized Bed Combustion
Place of publication: New York
Publisher: American Society of Mechanical Engineers
Source: orbit
Source-ID: 168259
Research output: Research - peer-review › Journal article – Annual report year: 1997

Modelling of N2O Reduction in a Circulating Fluidized Bed Boiler

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Chalmers University of Technology
Contributors: Johnsson, J. E., Åmand, L. E., Dam-Johansen, K., Leckner, B.
Pages: 338-343
Publication date: 1997

Host publication information
Title of host publication: Circulating Fluidized Bed Technology V, Proceedings of the Fifth International Conference on Circulating Fluidized Beds, May 28 to 31, 1996, Beijing
Place of publication: Beijing
Publisher: Science Press
Source: orbit

Residence time distributions (RTD) in a confined, cold swirling flow have been measured with a fast-response probe and helium as a tracer. The test-rig represented a scaled down version of a burner. The effect of variation of flow velocities and swirl angle on the flow pattern in the near-burner zone of the laboratory furnace-model were studied. RTD results have been used to derive a chemical reaction engineering model for the mixing process. The model is based on a combination of plug flow reactors and continuous stirred tank reactors, which represent the main flow characteristics in regard of mixing in the near burner zone. The model is well suited to handle mixing in complex flows with several zones of recirculation. Simulated RTD curves compared well with those of the experiment at the two swirl numbers studied. Modelling of the mixing is a prerequisite to handle the chemistry. A simplified, well characterised flow pattern makes it possible to investigate the importance of mixing intensity on the (pollution) chemistry in furnaces. The reactor model developed here will be the basis for the development of a chemical reaction engineering combustion model.
Residence Time Distributions in Confined Swirling Flames

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Single-particle behaviour in circulating fluidized beds

This paper describes an experimental investigation of single-particle behaviour in a cold pilot-scale model of a circulating fluidized bed combustor (CFBC). In the system, sand is recirculated by means of air. Pressure measurements along the riser are used to determine the suspension density. A radioactive tracking facility, which detects single radioactive particles, is developed and applied to determine the dynamic picture of the particle trajectories in the simulated boiler. The tracer particles are observed to move between the zone above and below the secondary air inlet with a mean frequency of about 1 Hz under the present operating conditions. This relatively high frequency is due to the fact that most of the particle trajectories take place just around the secondary air inlet. It is found that the upward particle velocity in the upper dilute transport zone decreases with the particle size or density, which results in a decreased number of particle observations for the larger particles with the riser height. The experiments show that the mean particle residence times in the zones above and below the secondary air inlet are almost independent of the particle characteristics. The overall mean particle residence time in the riser is proportional to the magnitude of the internal particle recirculation, which increases with the particle size.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Contributors: Erik Weinell, C., Dam-Johansen, K., Johnsson, J. E.
Pages: 241-252
Publication date: 1997
Peer-reviewed: Yes

Publication information
Journal: Powder Technology
Volume: 92
Issue number: 3
ISSN (Print): 0032-5910
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.47 SJR 0.982 SNIP 1.669
Web of Science (2017): Impact factor 3.23
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.16 SJR 0.975 SNIP 1.497
Web of Science (2016): Impact factor 2.942
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.99 SJR 0.939 SNIP 1.588
Web of Science (2015): Impact factor 2.759
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.67 SJR 0.874 SNIP 1.614
Web of Science (2014): Impact factor 2.349
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Sintering in biofuel and coal-biofuel fired FBCs. First annual progress report to EU JOULE III, OPTEB.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Dam-Johansen, K., Lin, W.
Publication date: 1997

Publication information
Original language: English
Source: orbit
Source-ID: 168385
Research output: Research - peer-review › Journal article – Annual report year: 1997
Nitrogen Chemistry in Fluidized Bed Combustion of Coal

The present Ph.D thesis describes an experimental and theoretical investigation of the formation and destruction of nitrogen oxides (NOx and N2O) in fluidized bed combustion (FBC) of coal. A review of the current knowledge of nitrogen chemistry in FBC is presented. The review covers both laboratory studies and pilot and full-scale observations. In the experimental part of the work, the heterogeneous oxidation of HCN catalyzed by two Danish limestones was investigated in a fixed bed laboratory reactor to establish how the reduction of the SO2 emission by addition of limestone to FBC influences the emission of NO and N2O. The results show that calcined limestone is an excellent catalyst for oxidation of HCN. The selectivity for the formation of NO is high, 50 to 70 % at typical FBC temperatures and concentrations. On the other hand the selectivity for the formation of N2O is very low, typically less than 5 %. Under conditions with high HCN concentrations at low O2 concentrations or at low temperatures, the selectivity for the formation of N2O is significantly higher, whereas the selectivity for NO formation is lower than it is under high temperature-high O2 conditions.

Furthermore, HCN may react with CaO forming CaCN2. Separate experiments with oxidation of CaCN2 showed that the selectivity for the formation of N2O was 20 to 25 %. The selectivity for the formation of NO was similar. These results indicate that simultaneous formation and oxidation of CaCN2 leads to the high selectivity for N2O observed under conditions where CaCN2 is formed. It was also found that the presence of NO enhanced the formation of N2O while NO was reduced. A preliminary reaction mechanism and mathematical model, considering the simultaneous catalytic oxidation of HCN and the formation and oxidation of CaCN2, was proposed and compared to experimental data. The agreement between model and experimental data was fair. Experiments were also conducted with simultaneous oxidation of HCN and sulphation of seven different types of limestone. The catalytic activity of the limestones decreases to a non-zero level with an increasing degree of sulphation. The selectivity for NO decreases with an increasing degree of sulphation of the limestone, but the N2O selectivity increases. The N2O selectivity by HCN oxidation over sulphated limestone is higher in the presence of NO. Furthermore, the catalytic activity decreases with an increasing inlet concentration of SO2. In the absence of O2 and SO2, CaSO4 decomposes to CaO and CaS in the presence of HCN. The results indicate that HCN is oxidized on two different types of site on the sulphated limestone. On one site there is competition between SO2 and HCN which results in the dependence of the catalytic activity on the SO2 concentration. It is possible that these sites are CaO, formed by decomposition of CaSO4 even in the presence of O2. These results partly explain the frequent observation that limestone addition to fluidized bed combustors results in a higher NO emission and a lower N2O emission. When limestone is added, the oxidation path for HCN changes from homogeneous oxidation with a high selectivity for N2O and a low selectivity for NO to a heterogeneous oxidation path over the limestone with a high NO selectivity and a low N2O selectivity. A mathematical model for the emission of NOx from FBC has been developed as part of a JOULE project. The model is based on the two-phase theory of fluidization for the bed with a Kunii-Levenspiel type freeboard model and includes submodels for coal devolatilization, combustion of volatiles and char and a detailed model of NO formation and reduction by homogeneous and heterogeneous reactions. The data for the estimation of kinetics of the heterogeneous reactions were measured by one of the partners in the project for char and bed material sampled from a pressurized FBC pilot plant burning Kiveton Park coal. Experimental data from the pilot plant were used for model verification. The simulations of the NO emission during staged combustion and NH3 injection for NO reduction were in qualitative agreement with the experimental data. A parametric study of the influence of operating conditions on the conversion of fuel-N to NO showed that in most cases the trends predicted by the model are in agreement with experimental observations in the literature. The simulations gave an increased insight into how and why different operating conditions influence the NO emission. The model contains a number of parameters the values of which are subjected to some uncertainty, and a sensitivity analysis of the predicted NO emission was carried out. The analysis showed that the predicted NO emission is sensitive to both hydrodynamic and combustion-related parameters. The most important hydrodynamic parameters were the minimum fluidization velocity, the gas interchange coefficient, the bubble size and the bubble rise velocity. The most important combustion parameters were the rate of CO and CH4 combustion and the fraction of CO produced from char combustion. By using a rate of production analysis, the important reactions in the NO model were identified. Laboratory measurements showed that 50 % of the fuel-N stays in the char after devolatilization and in the model it is assumed that this is oxidized to NO during char combustion. A significant amount of NO, 10-18 % of the fuel-N, was formed by oxidation of NH3 catalyzed by bed material. The reaction between NO and CO catalyzed by bed material is the most important reaction for reduction of NO at low to intermediate temperatures. At high temperatures, the reduction of NO by char and by CO catalyzed by char and the homogeneous reduction of NO by NH3 are also important. The oxidation of NH3 to N2 catalyzed by bed material is important for a low NO formation. The catalytic oxidation of NH3 over char to NO and N2 is not important because of the low char content in the bed. The results have demonstrated that mathematical modelling is a powerful tool to gain an increased understanding of the complicated process of NO formation and reduction in fluidized bed combustion.

General information
State: Published
Organisations: CHEC Research Centre, Department of Chemical and Biochemical Engineering
Contributors: Jensen, A. D., Dam-Johansen, K.
Number of pages: 256
Publication date: Jul 1996

Publication information
Place of publication: Kgs. Lyngby, Denmark
Publisher: Technical University of Denmark (DTU)
ISBN (Print): 87-90142-14-4
Original language: English
Experimental Investigation of NO Formation from Combustion of Wood and Straw in a Batch Combustor

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Haldor Topsoe AS, FLSmidth & Co. A/S
Contributors: Christensen, E., Jensen, L. S., Jensen, A., Dam-Johansen, K.
Pages: 137-150
Publication date: 1996

Host publication information
Title of host publication: Proceedings of the 3rd Nordic SOx-NOx Conference
Source: orbit
Source-ID: 166268
Research output: Research › Article in proceedings – Annual report year: 1996

Fluktuationer i affaldsforbrænding. Måbjergværket i Holstebro, 1996

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Bank, L. H., Dam-Johansen, K.
Publication date: 1996

Publication information
Original language: Danish
Source: orbit
Source-ID: 168516
Research output: Research - peer-review › Report – Annual report year: 1996

Full-scale co-firing of straw and coal

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Sk Forsyning A/S
Pages: 1584-1590
Publication date: 1996
Peer-reviewed: Yes

Publication information
Journal: Fuel
Volume: 75
Issue number: 13
Original language: English
Source: orbit
Source-ID: 165622
Research output: Research - peer-review › Journal article – Annual report year: 1996

Gas Analyses and Alkali Measurements at MKS1 - Final Report

General information
State: Published
GFEDBASE - A pure Substance Trace Element Thermochemical Database

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Frandsen, F., Dam-Johansen, K., Rasmussen, P.
Pages: 175-229
Publication date: 1996
Peer-reviewed: Yes

Impact of SO2 and NO on CO Oxidation under Post-Flame Conditions
An experimental and theoretical study of the effect of SO2 on moist CO oxidation with and without NO present was carried out under plug-flow conditions. The H/S/O thermochemistry and reaction subset was revised and a chemical kinetic model established that provide a good description of the effect of SO2 and NO on CO oxidation as well as the SO2/SO3 ratio in the products.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, New Jersey Institute of Technology
Contributors: Glarborg, P., Kubel, D., Dam-Johansen, K., Chiang, H., Bozzelli, J. W.
Pages: 773-790
Publication date: 1996
Peer-reviewed: Yes
Interactions of CO, NOx and H2O under Post-flame Conditions
An experimental and theoretical study of the impact of NO, NO2 and H2O on CO oxidation has been carried out. The experiments were performed in an isothermal quartz flow reactor at atmospheric pressure in the temperature range 800-1400 K. Inlet concentrations of NO and NO2 were 0-1% (vol) and 0-622 ppmv, respectively, while the water vapor level was varied in the ranges 1-32% (NO absent) and 1-10% (NO present). The results show that the concentration of water vapor has a strong effect on the CO oxidation process, partly because it controls the O/OH ratio of the radical pool, and partly due to the high efficiency of H2O in promoting H + O2 recombination, which causes a strong inhibition of CO oxidation at high levels. Presence of NO and NO2 has a significant
impact on moist CO oxidation, In low concentrations NO enhances CO consumption in the 900-1100 K range by converting HO2 to OH. In higher concentrations NO may catalyze recombination of radicals, thereby inhibiting the CO oxidation. The overall effect of NO depends on the radical pool composition, particularly the HO2 level and the O/OH ratio. NO2 is much more efficient than NO in removing radicals and presence of NO2 has a strong inhibiting effect on CO oxidation.

A chemical kinetic model has been established, which provides a good description of the effect of NO, NO2 and H2O on CO oxidation, based on the calculations, the rate determining steps in the system have been identified. The present results are significant for understanding the impact of NOx, on fuel oxidation and CO burnout in practical systems. Furthermore, they indicate that presence of NO2 impurities may affect significantly experiment on NO containing systems.

**General information**

State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Glarborg, P., Kubel, D., Kristensen, P. G., Hansen, J., Dam-Johansen, K.
Pages: 461-485
Publication date: 1996
Peer-reviewed: Yes

**Publication information**

Journal: Combustion Science and Technology
Volume: 110-111
ISSN (Print): 0010-2202
Ratings:

- BFI (2019): BFI-level 1
- Web of Science (2019): Indexed yes
- BFI (2018): BFI-level 1
- Web of Science (2018): Indexed yes
- BFI (2017): BFI-level 1
- Scopus rating (2017): CiteScore 1.59 SJR 0.683 SNIP 0.88
- Web of Science (2017): Impact factor 1.132
- Web of Science (2017): Indexed yes
- BFI (2016): BFI-level 1
- Scopus rating (2016): CiteScore 1.46 SJR 0.417 SNIP 1
- Web of Science (2016): Impact factor 1.241
- BFI (2015): BFI-level 1
- Scopus rating (2015): CiteScore 1.52 SJR 0.833 SNIP 0.976
- Web of Science (2015): Impact factor 1.193
- BFI (2014): BFI-level 1
- Scopus rating (2014): CiteScore 1.19 SJR 0.461 SNIP 0.904
- Web of Science (2014): Impact factor 0.991
- BFI (2013): BFI-level 1
- Scopus rating (2013): CiteScore 1.15 SJR 0.616 SNIP 0.922
- Web of Science (2013): Impact factor 0.976
- ISI indexed (2013): ISI indexed yes
- BFI (2012): BFI-level 1
- Scopus rating (2012): CiteScore 1.2 SJR 0.446 SNIP 1.027
- Web of Science (2012): Impact factor 1.011
- ISI indexed (2012): ISI indexed yes
- BFI (2011): BFI-level 1
- Scopus rating (2011): CiteScore 1.41 SJR 0.932 SNIP 1.015
- Web of Science (2011): Impact factor 0.857
- ISI indexed (2011): ISI indexed yes
- BFI (2010): BFI-level 1
- Scopus rating (2010): SJR 0.513 SNIP 1.19
- Web of Science (2010): Impact factor 1.105
- Web of Science (2010): Indexed yes
- BFI (2009): BFI-level 1
- Scopus rating (2009): SJR 1.119 SNIP 0.999
Lambda- sondemålinger på Herningværket, 1996

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Danish Gas Technology Centre A/S
Contributors: Kristensen, P. G., Dam-Johansen, K.
Publication date: 1996

Publication Information
Original language: Danish
Source: orbit
Source-ID: 168517
Research output: Research - peer-review › Report – Annual report year: 1996

Modeling N2O Reduction and Decomposition in a Circulating Fluidized bed Boiler

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Chalmers University of Technology
Contributors: Johnsson, J. E., Åmand, L., Dam-Johansen, K., Leckner, B.
Pages: 970-979
Publication date: 1996
Peer-reviewed: No

Publication information
Journal: Energy&Fuels
Volume: 10
Issue number: 4
Original language: English
Source: orbit
Source-ID: 166913
Research output: Research › Journal article – Annual report year: 1996

Modelling of catalytic oxidation of NH3 and reduction of NO on limestone during sulphur capture

A theoretical study of the complex transient system of simultaneous sulphur capture and catalytic reactions of N-containing compounds taking place on a single limestone particle is conducted. The numerical technique developed previously by the authors (Kiil et al. 1994) based on collocation on moving finite elements is used to solve the model equations. To our knowledge, this is the first serious attempt to model such transient systems in detail. The particle is divided into moving zones, described by the reaction between limestone and SO2, and each zone is assigned a certain
catalytic activity with respect to each species involved. An existing particle model, the Grain-Micrograin Model, which simulates sulfur capture on limestone under oxidizing conditions is considered in the modelling. Simulation results in good qualitative agreement with experimental data are obtained here for the catalytic chemistry of NH3 during simultaneous sulfur capture on a Stevns Chalk particle. The reduction of NO by NH3 over CaSO4 (which is the product of the reaction between SO2, O2 and limestone) was found to be important because this reaction could explain the change in selectivity with increased solid conversion observed experimentally. Simulations also suggested that it may be advantageous with respect to the emission of NO to use small instead of big limestone particles for desulfurisation in fluidised bed combustors due to the ways different sized particles capture SO2.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, University of Queensland
Contributors: Kiil, S., Bhatia, S. K., Dam-Johansen, K.
Pages: 587-601
Publication date: 1996
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 51
Issue number: 4
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.306
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
Web of Science (2016): Impact factor 2.895
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
Web of Science (2015): Impact factor 2.75
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.81 SJR 1.104 SNIP 1.629
Web of Science (2014): Impact factor 2.337
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.95 SJR 1.145 SNIP 1.843
Web of Science (2013): Impact factor 2.613
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.77 SJR 1.172 SNIP 1.828
Web of Science (2012): Impact factor 2.386
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 2.8 SJR 1.19 SNIP 1.678
Web of Science (2011): Impact factor 2.431
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Nitrogen Chemistry During Burnout in Fuel-Staged Combustion
A parametric study involving flow reactor experiments and chemical kinetic modeling is presented for the burnout zone in fuel-staging (reburning). The results provide guidelines for optimizing the reburn process and provide a test basis for verifying kinetic models for nitrogen chemistry at temperatures of 800 to 1350 K.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Kristensen, P. G., Glarborg, P., Dam-Johansen, K.
Pages: 211-222
Publication date: 1996
Peer-reviewed: Yes

Publication information
Journal: Combustion and Flame
Volume: 107
Issue number: 3
ISSN (Print): 0010-2180
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.27 SJR 2.427 SNIP 2.176
Web of Science (2017): Impact factor 4.494
Pressure Effects on the Thermal De-NOx Process
The effect of pressure on the thermal de-NOx process has been investigated in flow reactor experiments. The experiments were performed at pressures from 1 to 10 bar and temperatures ranging from 925 to 1375 K. The inlet O-2 level was varied from 1000 ppm to 10%, while NH3 and NO were maintained at 1000 and 500 ppm, respectively. At the highest pressure, CO was added to shift the regime for NO reduction to lower temperatures.

The results show that the pressure affects the location and the width of the temperature window for NO reduction. As the pressure is increased, both the lower and the higher boundaries for the process are shifted toward higher temperatures. Overall, the temperature range for NO reduction appears to be slightly broadened. The shift in chemistry toward higher temperatures is most pronounced at low oxygen concentrations. High oxygen levels act to counterbalance the inhibiting effect of the pressure but also cause a slight decrease in the NO reduction potential.

The results are consistent with recent atmospheric pressure experiments of thermal de-NOx covering a wide range of reactant partial pressures. Comparisons of the experimental data with the recent chemical kinetic model of Miller and Glarborg show satisfactory agreement. The implications of the results for application of thermal de-NOx in high-pressure systems, such as pressurized fluidized bed combustion and gas turbines, are discussed.
Proceedings of the 3rd Nordic SOx-NOx Conference

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Contributors: Dam-Johansen, K., Jensen, A., Østberg, M.
Publication date: 1996

Publication information
Original language: English
Source: orbit
Source-ID: 167908
Research output: Research › Conference article – Annual report year: 1996

Single Particle Tracing and Deterministic Chaos Analysis: Novel Tools to Investigate Circulating Fluidized Bed Behaviour

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering
Publication date: 1996

Host publication information
Title of host publication: Single Particle Tracing and Deterministic Chaos Analysis: Novel Tools to Investigate Circulating Fluidized Bed Behaviour
Catalytic reduction of nitric oxide by carbon monoxide over calcined limestone: reversible deactivation in the presence of carbon dioxide

The influence of carbon dioxide on nitric oxide reduction by carbon monoxide catalyzed over a porous limestone Stevns Chalk was studied in a fixed bed quartz reactor at 850°C under alternating oxidizing and reducing conditions, and under constant reducing conditions. The presence of carbon dioxide was found to inhibit the catalytic nitric oxide reduction. The nitric oxide reduction by carbon monoxide was found to fit the power law expression $r_{\text{NO}} = k \cdot [\text{NO}]^{1} \cdot [\text{CO}]^{0.8 - 0.9} \cdot [\text{CO}_2]^{-0.7}$ at ambient pressures, for 300-1200 ppmv NO, 2-6 vol.-% CO and 2-16 vol.-% CO$_2$. A simple mechanism for the nitric oxide reduction is proposed and a rate expression which agrees with the experimental results is derived. This study indicates that investigations of nitric oxide reduction by carbon monoxide catalyzed by CaO should be carried out in the presence of relevant concentrations of carbon dioxide.
Kinetics of catalytic formation of NOx from NH3 over CaO based sorbents during fluidized bed combustion of coal

General information
State: Published
Organisations: Delft University of Technology
Mass Transfer Method and Apparatus
The invention relates to a method for transferring mass between a flow of a first fluid, preferably a gas phase such as a combustion flue gas, and a flow of a second fluid, preferably a liquid phase, where the first fluid is contacted with the outer surface of porous (semi-permeable) membranes, e.g. polytetrafluoroethylene (PTFE, Teflon $m(3))$ membranes, in the form of hollow fibres having gas-containing pores and contacting the second fluid with the inner surface of the membranes. Useful membranes are characterized in that they e.g. have a porosity ($g(e)$) of at least 0.50, a mass transfer coefficient of e.g. at least 3 cm/s, and a tortuosity factor of e.g. at the most 1.4/$g(e)$ when the porosity $g(e)$ is lower than 0.80 and at the most 1.3/$g(e)$ when the porosity $g(e)$ is 0.80 or higher. The membranes may also be arranged in hollow tubular members where the mass transfer coefficient of the membranes is at least one tenth of the mass transfer coefficient of the gas phase. The invention also relates to an apparatus for the above-mentioned mass transfer having a tubular conduit with an open inlet end, where a part of the wall of the conduit comprises a plurality of hollow tubular members defining array(s) with interstices between the members allowing flow of the gas phase. The invention further relates to a process for absorption or desorption where porous membranes, e.g. the above-characterized membranes, are utilized and where an exceptionally low membrane area per cubic meter of gas handled is required.

Mutually Promoted Thermal Oxidation of Nitric Oxide and Organic Compounds
The invention relates to a process for mutually promoting thermal oxidation of nitric oxide and organic compounds, preferably in a combustion flue gas, in which the nitric oxide and the organic compounds are simultaneously oxidized in the presence of a catalyst and a reductant. The invention further relates to a process for mutually promoting thermal oxidation of nitric oxide and organic compounds in a combustion flue gas, in which the nitric oxide and the organic compounds are simultaneously oxidized in the presence of a catalyst and a reductant. The invention further relates to a process for mutually promoting thermal oxidation of nitric oxide and organic compounds in a combustion flue gas, in which the nitric oxide and the organic compounds are simultaneously oxidized in the presence of a catalyst and a reductant.
Nitrogen conversion. Comparison of a detailed chemical kinetic model and global reaction models

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Contributors: Pedersen, L. S., Glarborg, P., Dam-Johansen, K.
Pages: 763-766
Publication date: 1995

Solution of transient problems with steep gradients: novel front-tracking strategy
A finite element collocation method is formulated for heat and mass transfer problems involving a steep moving profile of the dependant variable. An efficient, parametrically convergent front-tracking procedure is developed based on a balance on a moving front, and the technique is applied and tested for the case of a gas-solid noncatalytic reaction in a porous solid at high Thiele modulus. Accurate and convergent steep profiles are obtained here for Thiele modulus larger than 50 for the case of slab as well as spherical geometry and found to match the analytical solution when it exists (such as for slab geometry).

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, University of Queensland
Contributors: Kiil, S., Bhatia, S. K., Dam-Johansen, K.
Pages: 2793-2799
Publication date: 1995
Peer-reviewed: Yes
The droplet diffusion model—An empirical model for micromixing in reacting gas phase systems

An empirical mixing model for mixing of reacting species in a fluid is proposed where the mixing process is divided into macromixing and micromixing. Macromixing is assumed to be instantaneous and is modelled by dividing the injected fluid into a number \( N_d \) of identical droplets, each surrounded by the same amount of bulk fluid. Micromixing is modelled as a molecular diffusion process in each droplet. The model can be used for any fluid residence time distribution \( E(t) \). The model is solved by means of collocation polynomials and numerical integration of the set of coupled differential equations using a third order semi implicit Runge-Kutta method. The proposed model is used to simulate pilot plant experiments of the selective non-catalytic reduction of NO by NH3. The experiments have previously been simulated using an ideal plug flow reactor model without success. Combining the empirical kinetic model for the reactions with this mixing model gives satisfying results when choosing the mixing parameter corresponding to a mixing time of 20–30 ms.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Contributors: Østberg, M., Dam-Johansen, K.
Pages: 2061-2067
Publication date: 1995
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 50
Issue number: 13
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.306
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
Web of Science (2016): Impact factor 2.895
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
Web of Science (2015): Impact factor 2.75
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.81 SJR 1.104 SNIP 1.629
Web of Science (2014): Impact factor 2.337
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.95 SJR 1.145 SNIP 1.843
Web of Science (2013): Impact factor 2.613
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.77 SJR 1.172 SNIP 1.828
The reaction of ammonia with nitrogen dioxide in a flow reactor: Implications for the NH2 + NO2 reaction

The NH3/NO2 system has been investigated experimentally in an isothermal flow reactor in the temperature range 850-1350 X. The experimental data were interpreted in terms of a detailed reaction mechanism. The flow reactor results, supported by a theoretical analysis of the NH2-NO2 complex, suggest that the NH2 + NO2 reaction has two major product channels, both proceeding without activation barriers:

(R20) NH2 ⇌ N2O + H2O
(R20) NH2 ⇌ H2NO + NO

Our findings indicate that the N2O + H2O channel is dominant at low temperatures while H2NO + NO dominates at high temperatures. The rate constant for reaction (R21) is estimated to be 3.5 x 10^12 cm^3/mol-s in the temperature range studied with an uncertainty of a factor of 3.
### Publication Information

- **Journal**: International Journal of Chemical Kinetics
- **Volume**: 27
- **Issue number**: 12
- **ISSN (Print)**: 0538-8066

### Ratings:

- **BFI (2019)**: BFI-level 1
- **Web of Science (2019)**: Indexed yes
- **BFI (2018)**: BFI-level 1
- **Web of Science (2018)**: Indexed yes
- **BFI (2017)**: BFI-level 1

**Scopus rating (2017)**:
- CiteScore 1.43
- SJR 0.543
- SNIP 0.755
- Impact factor 1.416
- Indexed yes

**Web of Science (2017)**:
- Impact factor 1.007
- Indexed yes

**BFI (2016)**: BFI-level 1

**Scopus rating (2016)**:
- CiteScore 1.47
- SJR 0.392
- SNIP 0.797
- Indexed yes

**Web of Science (2016)**:
- Impact factor 1.386
- Indexed yes

**BFI (2015)**: BFI-level 1

**Scopus rating (2015)**:
- CiteScore 2.01
- SJR 1.007
- SNIP 0.988
- Indexed yes

**Web of Science (2015)**:
- Impact factor 1.736
- Indexed yes

**BFI (2014)**: BFI-level 1

**Scopus rating (2014)**:
- CiteScore 1.61
- SJR 0.425
- SNIP 0.985
- Indexed yes

**Web of Science (2014)**:
- Impact factor 1.517

**BFI (2013)**: BFI-level 1

**Scopus rating (2013)**:
- CiteScore 1.47
- SJR 0.619
- SNIP 0.91
- Indexed yes

**Web of Science (2013)**:
- Impact factor 1.566

**ISI indexed (2013)**: ISI indexed yes

**Web of Science (2013)**: Indexed yes

**BFI (2012)**: BFI-level 1

**Scopus rating (2012)**:
- CiteScore 1.08
- SJR 0.376
- SNIP 0.733
- Indexed yes

**Web of Science (2012)**:
- Impact factor 1.187

**ISI indexed (2012)**: ISI indexed yes

**Web of Science (2012)**: Indexed yes

**BFI (2011)**: BFI-level 1

**Scopus rating (2011)**:
- CiteScore 1.29
- SJR 0.797
- SNIP 0.8

**Web of Science (2011)**:
- Impact factor 1.007

**ISI indexed (2011)**: ISI indexed yes

**BFI (2010)**: BFI-level 1

**Scopus rating (2010)**:
- SJR 0.427
- SNIP 0.944

**Web of Science (2010)**:
- Impact factor 1.154

**BFI (2009)**: BFI-level 1

**Scopus rating (2009)**:
- SJR 0.835
- SNIP 0.985

**BFI (2008)**: BFI-level 1

**Scopus rating (2008)**:
- SJR 0.446
- SNIP 0.986

**Web of Science (2008)**: Indexed yes

**Scopus rating (2007)**: SJR 0.752

**Scopus rating (2006)**: SJR 0.587

**Scopus rating (2005)**: SJR 0.595

**Scopus rating (2004)**: SJR 0.568

**Scopus rating (2003)**: SJR 0.711

**Web of Science (2003)**: Indexed yes
The thermal DeNOx process: Influence of partial pressures and temperature

The effect of partial pressures of the reactants in the Thermal DeNOx process has been investigated in flow reactor experiments. The experiments were performed at atmospheric pressure for temperatures ranging from 923 to 1373 K. Initial concentrations were varied for NH3 and O2 (400–200, 1000–500, 2800–1400 ppm) and O2 (0–50%). The data confirm earlier observations that in the temperature range covered, presence of O2 is required in order for NO to be reduced by NH3. As the initial O2 concentration is increased, the lower boundary for the process is shifted towards lower temperatures. The temperature range for NO reduction is widened, but the NO reduction potential decreases. At high oxygen concentrations the maximum NOx reduction is below 40%. Under these conditions, significant amounts of NO2 and N2O are formed. Two mechanisms for N2O formation in Thermal DeNOx have been identified. One is active at higher temperatures and low O2 concentrations, while the other, which presumably involves NO2 as a precursor, is dominant at lower temperatures and high O2 levels. The implications of the results for application of Thermal DeNOx in high pressure systems such as pressurized fluidized bed combustion is discussed. Comparisons of the experimental data with recent chemical kinetic models indicate that the detailed chemistry of the Thermal DeNOx system is not completely understood.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Technical University of Denmark
Contributors: Kasuya, F., Glarborg, P., Johnsson, J. E., Dam-Johansen, K.
Pages: 1455-1466
Publication date: 1995
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 50
Issue number: 9
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.306
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
Web of Science (2016): Impact factor 2.895
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
Web of Science (2015): Impact factor 2.75
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
A flow reactor study of HNCO oxidation chemistry

An experimental and theoretical study of HNCO oxidation has been carried out. The experiments were performed in an isothermal quartz flow reactor, and the effects of temperature, CO concentration, and NO concentration were investigated at atmospheric pressure in the temperature range 1025-1425 K. The reaction mechanism for \text{RAPRENO}_x\ proposed by
Miller and Bowman (1991) has been updated based on the present result as well as recent advances in the understanding of important elementary steps. Model predictions with the revised mechanism are in good agreement with our experimental data as well as data from the literature. Oxidation of HNCO proceeds mainly through NCO, which subsequently is oxidized to NO or reacts with NO to form N2 and N2O. This sequence of reactions is chain terminating, and for reaction to occur, radicals must be generated either by alternative oxidation pathways or by the presence of other combustibles. A chain-branching oxidation route initiated by reaction of HNCO with O2 is proposed in order to explain the observed HNCO decay in the absence of inlet CO. Addition of CO enhances HNCO oxidation and the RAPRENOx chemistry, since CO oxidation acts to replenish the radical pool. The experimental results show that the mutual presence of HNCO and NO strongly inhibits CO oxidation at lower temperatures. In addition to the chain terminating HNCO/NCO reactions, a second inhibition mechanism involving NO is necessary to explain this behavior. This mechanism is presently believed to be NO NO2 interconversion, but additional work is needed to confirm this. Further progress in the understanding of the HNCO chemistry is dependent on an accurate determination of the rate and/or mechanism of a number of key reactions, including HNCO + OH, HNCO + O2, NCO + NO and NO + O + M.
Characterization of a full-scale, single-burner pulverized coal boiler: temperatures, gas concentrations and nitrogen oxides

Local temperatures and gas concentrations were measured in a 17 MW top-fired pulverized coal furnace. A specially designed suction pyrometer was used for thermocouple temperature measurements as well as withdrawal of gas samples from the furnace. The gas sampling system was carefully tested to make sure that the sample gas was efficiently quenched. Gas samples were analysed for \( \text{O}_2, \text{CO}, \text{CO}_2, \text{NO}, \text{NO}_2 \) and \( \text{SO}_2 \). The effects of furnace load, primary:secondary air ratio and total excess air level were investigated. NO emission increased with the total excess air level, but was less sensitive to variations in load and in distribution of combustion air. These results are discussed in terms of NO formation mechanisms as well as burner and furnace characteristics. The experimental data provide good possibilities for scaling and modelling studies, in that they characterize a full-scale, single-burner pulverized coal system with a simple geometry.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Contributors: Illerup, J. B., Dam-Johansen, K., Glarborg, P.
Pages: 492-499
Publication date: 1994
Peer-reviewed: Yes

Publication information
Journal: Fuel
Volume: 73
Empirical modeling of the selective non-catalytic reduction of NO comparison with large-scale experiments and detailed kinetic modeling

An empirical model for the selective non-catalytic reduction (SNR) of NO with NH₃ as reductant is proposed. The model is based on two empirical reactions: one reaction describing the oxidation of NH₃ to NO, and the other the reduction of NO by reaction with NH₃ to N₂. It is shown that the model describes the influence of the major parameters that can be varied in the SNR process (injection temperature, temperature gradient, residence time, amount of injected NH₃ and amount of injected additive). The model predictions are compared to experiments carried out in a fluidized bed boiler and in a pilot plant using flue gas withdrawn from a coal fired utility boiler and it is compared with the kinetic model of Miller and Bowman (1989). When ideal mixing between the injected NH₃ and the flue gas can be assumed, as in the cyclone of the fluidized bed boiler, a good agreement between the model predictions and the experiments is obtained. The empirical model gives a better description of the result for a fluidized bed boiler than the kinetic model of Miller and Bowman (1989). In the coal fired pilot plant the mixing process is not ideal, this seems to influence the process performance.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Technical University of Denmark, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Contributors: Østberg, M., Dam-Johansen, K.
Pages: 1897-1904
Publication date: 1994
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 49
Issue number: 12
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.306
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
Web of Science (2016): Impact factor 2.895
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
Interaction between emissions of sulfur dioxide and nitrogen oxides in fluidized bed combustion

NH₃ is an important volatile N-containing compound and a precursor for NOₓ formation in fluidized bed combustion (FBC). This work focuses on the influence of the sulfation process on the oxidation of NH₃ to NO catalysed by different CaO based sorbents and other bed materials (sand, Al₂O₃). Experiments of simultaneous sorbent sulfation and oxidation of NH₃ catalysed by the sorbents were performed in a laboratory fixed bed reactor in order to study changing catalytic activity. The influence of SO₂ on the oxidation of NH₃ to NO for different bed materials was investigated as well. The results show that desulfurization interferes with the catalytic conversion of NH₃ to NO in two ways. First, CaO based sorbents are active catalysts for the oxidation of NH₃ to NO; this catalytic activity decreases with an increase in the conversion of CaO to CaSO₄. For the limestones, which are subject to pore plugging, the sorbents totally lose their activity for NO formation from NH₃ when the maximum conversion of CaO to CaSO₄ is reached. Second, the catalytic formation rate of NO decreases in the presence of SO₂ for some bed materials. This means that the presence of SO₂ inhibits oxidation of NH₃ to NO. Moreover, it appears that SO₂ inhibits the decomposition of N₂O on the surface of the catalysts as well.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Delft University of Technology
Contributors: Lin, W., Johnsson, J. E., Dam-Johansen, K., van den Bleek, C. M.
Pages: 1202-1208
Publication date: 1994
Peer-reviewed: Yes

Publication information
Journal: Fuel
Volume: 73
Issue number: 7
ISSN (Print): 0016-2361
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.4 SJR 1.891 SNIP 2.127
Web of Science (2017): Impact factor 4.908
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.9 SJR 1.736 SNIP 2.207
Web of Science (2016): Impact factor 4.601
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.46 SJR 1.781 SNIP 2.123
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 4.14 SJR 1.634 SNIP 2.294
Web of Science (2014): Impact factor 3.52
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.31 SJR 1.762 SNIP 2.544
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 3.99 SJR 1.813 SNIP 2.425
Web of Science (2012): Impact factor 3.357
ISI indexed (2012): ISI indexed yes
Kinetics of homogeneous nitrous oxide decomposition

The major uncertainties in the consumption mechanism for N₂O are related to the efficiency of various components as collision partners in N₂O dissociation and to the rate constant for the N₂O + OH reaction. In this work thermal dissociation of N₂O in different carrier gases has been measured at atmospheric pressure in the temperature range 1000-1400 K. Based on these, as well as earlier data from this laboratory, collision efficiencies were determined for O₂, CO₂, N₂, and H₂O. The relative efficiencies compared to Ar were found to 1.4 ± 0.3, 3.0 ± 0.6, 1.7 ± 0.3, and 12 ± 3.5, respectively. The fast rate measured for N₂O + H₂O indicates that the commonly accepted rate constant for N₂O dissociation at the high-pressure limit may be too low around 1300 K. The reaction between N₂O and OH was investigated by addition of N₂O to moist CO oxidization experiments. The N₂O + OH reaction was found to be very slow under the present conditions, with an upper limit of 3 · 10⁻²³ cm³/mole-s for the rate constant at 1250 K. In agreement with recent theoretical studies, this makes the reaction more than one order of magnitude slower than estimates currently used in modeling. The implications of the present results for modeling N₂O chemistry in fluidized bed and other combustion systems are discussed.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Contributors: Glarborg, P., Johnsson, J. E., Dam-Johansen, K.
Pages: 523-532
Publication date: 1994
Modeling the thermal DENOx process in flow reactors. Surface effects and Nitrous Oxide formation

We have investigated the impact of surface reactions such as NH3 decomposition and radical adsorption on quartz flow reactor data for Thermal DeNOx using a model that accounts for surface chemistry as well as molecular transport. Our calculations support experimental observations that surface effects are not important for experiments carried out in low surface to volume quartz reactors. The reaction mechanism for Thermal DeNOx has been revised in order to reflect recent experimental results. Among the important changes are a smaller chain branching ratio for the NH2 + NO reaction and a shorter NNH lifetime than previously used in modeling. The revised mechanism has been tested against a range of experimental flow reactor data for Thermal DeNOx with reasonable results. The formation of N2O in Thermal DeNOx has been modelled and calculations show good agreement with experimental data. The important reactions in formation and destruction of N2O have been identified. Our calculations indicate that N2O is formed primarily from the reaction between NH and NO, even though the NH2 + NO2 reaction possibly contributes at lower temperatures. At higher temperatures N2O concentrations are limited by thermal dissociation of N2O and by reaction with radicals, primarily OH. © 1994 John Wiley & Sons, Inc.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Sandia National Laboratories CA, Sandia National Laboratories NM
Contributors: Glarborg, P., Dam-Johansen, K., Miller, J. A., Kee, R. J., Coltrin, M. E.
Pages: 421-436
Publication date: 1994
Peer-reviewed: Yes

Publication information
Journal: International Journal of Chemical Kinetics
Volume: 26
Issue number: 4
ISSN (Print): 0538-8066
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.43 SJR 0.543 SNIP 0.755
Web of Science (2017): Impact factor 1.416
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.47 SJR 0.392 SNIP 0.797
Web of Science (2016): Impact factor 1.386
Web of Science (2016): Indexed yes
Trace elements from combustion and gasification of coal—An equilibrium approach

The fate of several trace elements in the thermal conversion of coal has been investigated, assuming global equilibrium and using an in-house database and a Fortran-77 computer code for the calculations. The format and content of the database DGFDDBASE, containing reduced data on $\Delta G^\circ_f (T)$ for approximately 800 chemical species of the elements Al, As, B, Be, Br, C, Ca, Cd, Cl, Co, Cr, F, Fe, Ga, Ge, H, Hg, K, Mg, N, Na, Ni, O, P, Pb, S, Sb, Se, Si, Sn, Ti, V and Zn are described. Results of thermodynamic equilibrium calculations performed using 'the total Gibbs free energy minimization' program MINGTSYS on simple systems containing one of the trace elements As, B, Be, Cd, Co, Cr, Ga, Ge, Hg, Ni, P, Pb, Sb, Se, Sn, Ti, V and Zn are presented and compared with results from the literature. Combustion as well as
gasification conditions have been considered. At oxidizing conditions all the trace elements considered form at least one stable condensed phase in the temperature range from 300-2000 K. Regarding the condensed phase being stable at the lowest temperatures, the trace elements can be divided into two groups, the first of sulfate forming elements (this group includes the elements Be, Cd, Co, Cr, Hg, Ni, Pb, Sb, Sn, V, and Zn) and the latter of oxide-hydroxide forming elements (this group includes the elements: As, B, Ga, Ge, P, Se and Ti). At reducing conditions, the behavior of the trace elements considered is complex, and no simple classification of the elements is possible.
Wet oxidation of residual product from spray absorption of sulphur dioxide

The oxidation of calcium sulphite in aqueous slurries of residual product from spray absorption of sulphur dioxide was studied under heterogeneous conditions typical of wet scrubbers. The observed rate of oxidation without additional catalyst was found to be of 0th and 1st order in the sulphite concentration and the partial pressure of oxygen, respectively. With manganeous sulphate added as a catalyst, the order was about 0.5 and 1.0, respectively. Both the residual product and the oxidation product were analysed with respect to composition and characteristics. The oxidation product contained more than 90 wt% gypsum.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Technical University of Denmark
Contributors: Hjuler, K., Dam-Johansen, K.
Pages: 4515-4521
Publication date: 1994
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 49
Issue number: 24 PART A
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.306
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Design of a flue gas probe for ammonia measurement
The emission of nitrogen oxides from combustion can be limited by selective catalytic reduction (SCR) and selective non-catalytic reduction (SNR) by ammonia. In order to control the ammonia slip in these processes it is desirable to measure the ammonia outlet concentration continuously. The problems in doing this are discussed, among which are homogeneous and heterogeneous reactions of ammonia with nitric oxide in the sampling system. The design and test of a diluting flue gas probe is presented, where ammonia is converted to and detected as nitric oxide. The efficiency of various converter designs for the probe was studied in the laboratory.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Technical University of Denmark
Contributors: Hjuler, K., Dam-Johansen, K.
Pages: 703-709
Publication date: 1993
Peer-reviewed: Yes

Publication information
Journal: Analytica Chimica Acta
Volume: 282
Issue number: 3
ISSN (Print): 0003-2670
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.06
Web of Science (2017): Impact factor 1.363
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 5.01
Web of Science (2016): Impact factor 1.74
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.94
Web of Science (2015): Impact factor 1.682
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 4.64
Web of Science (2014): Impact factor 2.003
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 4.74
Web of Science (2013): Impact factor 1.547
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 4.55
Web of Science (2012): Impact factor 1.747
ISI indexed (2012): ISI indexed yes
High-temperature reaction between sulfur dioxide and limestone-VI. The influence of high pressure

The influence of total pressures and partial pressures of carbon dioxide on the reaction between SO2 and large particles of limestone was studied. The experiments were conducted in a laboratory fixed-bed reactor made of quartz at temperatures up to 950°C, total pressures up to 10 bar, and carbon dioxide partial pressures up to 2 bar. Two types of limestone were tested. At carbon dioxide partial pressures exceeding the calcination equilibrium pressure of limestone, the ultimate degree of sulfation was significantly lower at 850°C than at 750°C, most probably due to sintering of the calcium carbonate. Partly sulfated particles were less sensitive to heat treatment than unreacted and uncalcined limestone. Under calcined conditions, a considerable increase in the ultimate degree of sulfation at 850°C was observed with both types of limestone. A part of the explanation may be the high melting point of CaO compared to CaCO3, resulting in a much slower sintering rate. At 950°C the limestone calcines in the pressure range studied and a relatively high ultimate degree of sulfation was achieved.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Technical University of Denmark
Contributors: Illerup, J. B., Dam-Johansen, K., Lundén, K.
Pages: 2151-2157
Publication date: 1993
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 48
Issue number: 11
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
High-temperature reaction between sulphur dioxide and limestone-V. The effect of periodically changing oxidizing and reducing conditions

Sulphur capture by limestone has been studied in a laboratory reactor developed to simulate the periodically changing oxidizing and reducing conditions experienced by limestone particles in a fluidized-bed combustor. Under oxidizing conditions, sulphur is captured as CaSO₄. Under reducing conditions, and in the presence of CO, sulphur is captured as CaS. Transformation of CaSO₄ to CaS and vice versa appears to proceed via CaO. Substituting CO with H₂ reducing agent causes an increase in the rate of reductive decomposition of CaSO₄, and no formation of CaS is observed. Using CH₄ neither reductive decomposition of CaSO₄ nor formation of CaS is observed. The sulphur capacity of 14 European limestones was studied under constant oxidizing as well as under alternating oxidizing and reducing conditions. The relative ranking of the limestones appears to be little influenced by the reaction conditions. Generally, a slight reduction in the sulphur capacity is observed under alternating conditions. The exceptions are limestones with a high content of Fe₂O₃, which lowers the sulphur capacity significantly, presumably due to reduced stability of the sulphated limestone under reducing conditions. Rates of CaS formation and of reductive decomposition of CaSO₄ differ greatly for different limestones. Reduction of particle size increases the SO₂ release due to CaS oxidation but decreases the release of SO₂ due to reductive decomposition. Both CaS oxidation and reductive decomposition of CaSO₄ may lead to a diminished degree of desulphurization in real combustors. A temperature optimum observed for desulphurization in fluidized-bed combustors appears to be caused primarily by the competition between sulphur capture and sulphur release, the latter of which becomes increasingly important at high temperatures.

General information

State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Technical University of Denmark
Contributors: Hansen, P. F. B., Dam-Johansen, K., Østergaard, K.
Pages: 1325-1341
Publication date: 1993
Peer-reviewed: Yes

Publication information

Journal: Chemical Engineering Science
Volume: 48
Issue number: 7
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.306
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
Web of Science (2016): Impact factor 2.895
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
Web of Science (2015): Impact factor 2.75
Web of Science (2015): Indexed yes
Homogeneous nitrous oxide formation and destruction under combustion conditions

N₂O decomposition and formation during the oxidation of NH₃ and HCN were studied in a quartz flow reactor in the presence of CO, NO and other gases. The emphasis is on the influence of CO and NO. In addition, the homogeneous
nitrogen chemistry of fluidized bed combustion and the selective noncatalytic reduction of NO (SNR) are discussed. The rate of N₂O decomposition in N₂ agrees with a first-order rate expression. The presence of CO or H₂ increases the decomposition rate regardless of the additional presence of O₂. For the formation of N₂O, HCN oxidation is more efficient than NH₃ oxidation. The presence of NO increases the amount of N₂O formed during the oxidation of HCN or NH₃. CO moves the N₂O formation toward lower temperatures. H₂O increases the reaction rate where few components are present, whereas H₂O has little influence in the presence of large amounts of a combustible component such as CO. There are indications that NO is a necessary intermediate for any significant formation of N₂O during the oxidation of NH₃ and HCN. NO reduction is obtained when NO is initially present during oxidation of both NH₃ and HCN. These results are comparable to the respective SNR results with reductant ammonia and urea.

**General information**

State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Technical University of Denmark
Contributors: Hulgaard, T., Dam-Johansen, K.
Pages: 1342-1354
Publication date: 1993
Peer-reviewed: Yes

**Publication information**

Journal: AIChE Journal
Volume: 39
Issue number: 8
ISSN (Print): 0001-1541
Ratings:  
BFI (2019): BFI-level 2  
Web of Science (2019): Indexed yes  
BFI (2018): BFI-level 2  
Web of Science (2018): Indexed yes  
BFI (2017): BFI-level 2  
Scopus rating (2017): CiteScore 3.31 SJR 1.015 SNIP 1.331  
Web of Science (2017): Impact factor 3.326  
Web of Science (2017): Indexed yes  
BFI (2016): BFI-level 2  
Scopus rating (2016): CiteScore 3.11 SJR 1.035 SNIP 1.29  
Web of Science (2016): Impact factor 2.836  
Web of Science (2016): Indexed yes  
BFI (2015): BFI-level 2  
Scopus rating (2015): CiteScore 3.03 SJR 1.085 SNIP 1.428  
Web of Science (2015): Impact factor 2.98  
Web of Science (2015): Indexed yes  
BFI (2014): BFI-level 2  
Scopus rating (2014): CiteScore 2.86 SJR 1.066 SNIP 1.337  
Web of Science (2014): Impact factor 2.748  
Web of Science (2014): Indexed yes  
BFI (2013): BFI-level 2  
Scopus rating (2013): CiteScore 2.59 SJR 1.053 SNIP 1.355  
Web of Science (2013): Impact factor 2.581  
ISI indexed (2013): ISI indexed yes  
Web of Science (2013): Indexed yes  
BFI (2012): BFI-level 2  
Scopus rating (2012): CiteScore 2.46 SJR 0.98 SNIP 1.437  
Web of Science (2012): Impact factor 2.493  
ISI indexed (2012): ISI indexed yes  
Web of Science (2012): Indexed yes  
BFI (2011): BFI-level 2  
Scopus rating (2011): CiteScore 2.31 SJR 0.994 SNIP 1.248  
Web of Science (2011): Impact factor 2.261
Influence of SO$_2$ on the NO/N$_2$O chemistry in fluidized bed combustion

**General information**

State: Published

Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation

Coatings Science and Technology Centre (CoaST), Chalmers University of Technology

Contributors: Dam-Johansen, K., Åmand, L., Leckner, B.

Pages: 565-571

Publication date: 1993

Peer-reviewed: Yes

**Publication information**

Journal: Fuel

Volume: 72

Issue number: 4

ISSN (Print): 0016-2361

Ratings:

BFI (2019): BFI-level 2

Web of Science (2019): Indexed yes

BFI (2018): BFI-level 2

Web of Science (2018): Indexed yes

BFI (2017): BFI-level 2
Influence of SO₂ on the NON₂O chemistry in fluidized bed combustion: 2. Interpretation of full-scale observations based on laboratory experiments

In circulating fluidized bed combustion of coal, significant interactions between desulfurization by limestone and emissions of nitrogen oxides (NO, N₂O) are generally observed. In order to facilitate interpretation of experimental results obtained in a 12 MW circulating fluidized bed boiler, a series of laboratory tests have been carried out. The tests include homogeneous CO and HCN oxidation in the presence of different concentrations of SO₂, CO oxidation catalysed by calcined and partly sulfated limestone particles, and formation and reduction of NO and N₂O over bed material containing char. The presence of SO₂ in the gas is shown to decrease the rate of homogeneous CO and HCN oxidation and thereby change the product distribution of the nitrogen-containing species. Unlike sulfated limestone, calcined limestone (CaO) is shown to be a good catalyst for oxidation of CO. A lower mean CO concentration is therefore expected in fluidized bed combustors during injection of limestone. This indirectly influences the nitrogen chemistry. Finally, the influence of NO and O₂ on the formation of N₂O from char was studied.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Chalmers University of Technology
Contributors: Dam-Johansen, K., Åmand, L., Leckner, B.
Pages: 565-571
Publication date: 1993
Peer-reviewed: Yes

Publication information
Journal: Fuel
Volume: 72
Issue number: 4
ISSN (Print): 0016-2361
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.4 SJR 1.891 SNIP 2.127
Web of Science (2017): Impact factor 4.908
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.9 SJR 1.736 SNIP 2.207
Web of Science (2016): Impact factor 4.601
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 4.46 SJR 1.781 SNIP 2.123
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 4.14 SJR 1.634 SNIP 2.294
Web of Science (2014): Impact factor 3.52
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.31 SJR 1.762 SNIP 2.544
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Neural Modeling of the Selective Noncatalytic Reduction Of Nitric-Oxide in a laboratory Reactor And A Full-Scale Plant

Neural networks have been used for estimating multivariate models of the selective non-catalytic reduction (SNR) of NO with NH3. A neural network model accurately fitted the data from well-defined laboratory experiments; this model predicted NH3 and NO(x) concentrations at the reactor outlet as functions of a wide variety of parameters. The control scheme of a commercial SNR process was optimised by a different neural model, designed from experimental measurements of NH3 and NO(x) emissions as functions of various operational parameters—Discrete prediction of NH3 was necessary because of limited analytical accuracy. The results demonstrate the power of neural networks in the static input/output modelling of non-linear processes, either generating an accurate model from an accurate set of data or extracting an adequate model from a noisy set of data.

General information
State: Published
Organisations: Unknown external organisation
Contributors: Bendtsen, A. B., Dam-Johansen, K., Jensen, N., Jodal, M., Lauridsen, T.
Pages: 40-46
Publication date: 1993
Simultaneous NOx–SOx removal by ammonia using methanol injection and partial flue gas condensation

**General information**

**State:** Published  
**Organisations:** Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Technical University of Denmark  
**Contributors:** Hjuler, K., Dam-Johansen, K.  
**Pages:** 300-305  
**Publication date:** 1993  
**Peer-reviewed:** Yes
Catalytic reduction of NO and N<sub>2</sub>O on limestone during sulfur capture under fluidized bed combustion conditions

Sulfur retention by limestone (CaCO<sub>3</sub>) under fluidized bed combustion conditions is the net effect of a competition between sulfur capture and sulfur release during which the composition of the Ca surface changes continuously between CaO, CaS and CaSO<sub>4</sub>, the ultimate product being CaSO<sub>4</sub>. The presence of limestone in fluidized bed combustors interacts with the nitrogen chemistry: it acts as a catalyst for volatile-N oxidation to NO and as a catalyst for the reduction of NO and N<sub>2</sub>O, the latter being the subject of this paper. The results show that CaS and CaO are active catalysts for reduction of NO and N<sub>2</sub>O, whereas CaSO<sub>4</sub> and CaCO<sub>3</sub> are poor catalysts. N<sub>2</sub> decomposes readily over CaO under oxidizing conditions which leave NO unaffected. Under reducing conditions, both NO and N<sub>2</sub>O are reduced simultaneously but apparently not at the same active sites. The catalytic activity of limestone decreases during sulfation due to a loss in porosity and a lower activity of the CaSO<sub>4</sub> formed. The highest catalytic activity for NO and N<sub>2</sub>O reduction was found for limestone with a high sulfur capacity. The presence of H<sub>2</sub>O appears not to affect the heterogeneous reactions involving NO and N<sub>2</sub>O.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Technical University of Denmark
Contributors: Hansen, P. F., Dam-Johansen, K., Johnsson, J. E., Hulgaard, T.
Pages: 2419-2424
Publication date: 1992
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 47
Issue number: 9-11
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.006
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
Web of Science (2016): Impact factor 2.895
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
Web of Science (2015): Impact factor 2.75
Hydrogen Chloride Reaction with Lime and Limestone: Kinetics and Sorption Capacity

The capacity of solid slaked lime and limestone for binding HCl from a gas phase has been investigated in the temperature range 60-1000 °C. The binding capacity is largest in the range 500-600 °C. However, for slaked lime in the presence of water, a large binding capacity is observed also below 150 °C. This is ascribed to the formation of a partially liquid product phase. At temperatures exceeding 500 °C the binding capacity is limited by chemical equilibrium between gas and solid. For the range of properties studied the binding capacity is independent of particle size and only depends slightly on specific surface area. The kinetics of the binding reaction is governed by diffusion in the solid phase which is proved to follow an unreacted grain-core model. Diffusion coefficient for mass transport in the grain is reported for the temperature range 80-250 °C.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Technical University of Denmark
Contributors: Erik Weinell, C., Jensen, P. I., Dam-Johansen, K., Livbjerg, H.
Number of pages: 8
Pages: 164-171
Publication date: 1992
Peer-reviewed: Yes

Publication information
Journal: Industrial and Engineering Chemistry Research
Volume: 31
Issue number: 1
ISSN (Print): 0888-5885
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.4 SJR 0.978 SNIP 1.203
Web of Science (2017): Impact factor 3.141
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.1 SJR 0.95 SNIP 1.155
Web of Science (2016): Impact factor 2.843
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.87 SJR 0.938 SNIP 1.145
Web of Science (2015): Impact factor 2.567
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.85 SJR 1.009 SNIP 1.287
Web of Science (2014): Impact factor 2.587
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.6 SJR 0.975 SNIP 1.232
Web of Science (2013): Impact factor 2.235
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.56 SJR 1.054 SNIP 1.32
Web of Science (2012): Impact factor 2.206
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 2.58 SJR 1.076 SNIP 1.236
Kinetics of the gas-phase reaction between nitric oxide, ammonia and oxygen

For the purpose of developing a simple and quantitative description of the rate of reactions occurring in the Thermal DeNO\textsubscript{x} process, the kinetics of the homogeneous reaction between NO and NH\textsubscript{3} with excess of O\textsubscript{2} has been studied in an isothermal plug flow reactor. Temperature windows of NO reduction were observed with the optimum temperature decreasing with increasing residence time. The degree of reduction of NO increases with residence time at lower temperatures but is sensitive to residence time only at very short residence times at higher temperatures. The degree of conversion of NH\textsubscript{3} increases with both temperature and residence time. A simple model has been proposed to describe the reaction rates: \[ r_{\text{NO}} = k_{\text{ax}} [\text{NH}_3] - k_r [\text{NH}_3] [\text{NO}] \]
\[ r_{\text{NH}_3} = -k_{\text{ax}} [\text{NH}_3] - k_r [\text{NH}_3] [\text{NO}] \]
The two rate constants in the model were estimated based on the experimental data obtained in the present plug flow reactor at about 4% (vol.) oxygen: \[ k_{\text{ax}} = (2.21 \pm 0.33) \times 10^{14} \text{exp}[-(38160 \pm 170)/T], \text{I/s} \]
\[ k_r = (2.45 \pm 0.49) \times 10^{14} \text{exp}[-(29400 \pm 250)/T], \text{m}^3\text{mol. s} \]
It is verified that the kinetic model can give a satisfactory prediction of the experimental results under different conditions.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), University of Surrey, Technical University of Denmark
Contributors: Duo, W., Dam-Johansen, K., Østergaard, K.
Pages: 1014-1020
Publication date: 1992
Peer-reviewed: Yes
Mechanism and Kinetics of the Reaction between Sulfur Dioxide and Ammonia in Flue Gas

The reaction between sulfur dioxide and ammonia in flue gas is of importance in understanding scaling on process equipment and monitoring systems in a number of flue gas cleaning processes. The reaction was studied at atmospheric pressure using simulated flue gas, 1.5-12.0-mm-internal diameter tube reactors, and flows ranging from 0.5 to 4.0 (N L)/min. The reaction temperature, sulfur dioxide concentration, and ammonia concentration were 40-80 °C, 60-1000 ppm, and 120-2000 ppm, respectively. The water content of the gas was typically 6 vol % and the oxygen content 5 vol %. The first step of the reaction is the formation of liquidlike ammonium salt containing sulfur in oxidation state IV on surfaces. With oxygen and small amounts (5 ppm) of nitrogen dioxide present, S(IV) is irreversibly oxidized to S(VI), and the product becomes solid and thermally stable. This product contains primarily ammonium sulfate. An overall mechanism for the reaction involving two intermediary species is proposed, and a simple three-parameter expression for the reaction rate has been developed from the mechanism.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation
Coatings Science and Technology Centre (CoaST), Technical University of Denmark
Contributors: Hjuler, K., Dam-Johansen, K.
Pages: 2110-2118
Publication date: 1992
Peer-reviewed: Yes

Publication information
Journal: Industrial and Engineering Chemistry Research
Volume: 31
Issue number: 9
ISSN (Print): 0888-5885
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
Scopus rating (2017): CiteScore 3.4 SJR 0.978 SNIP 1.203
Web of Science (2017): Impact factor 3.141
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.1 SJR 0.95 SNIP 1.155
Web of Science (2016): Impact factor 2.843
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.87 SJR 0.938 SNIP 1.145
Web of Science (2015): Impact factor 2.567
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.85 SJR 1.009 SNIP 1.287
Web of Science (2014): Impact factor 2.587
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.6 SJR 0.975 SNIP 1.232
Web of Science (2013): Impact factor 2.235
ISI indexed (2013): ISI indexed yes
Nitrous oxide sampling, analysis, and emission measurements from various combustion systems

Nitrous oxide (N\textsubscript{2}O) emissions from various combustion systems were measured by use of two analytical methods, the performance of which was evaluated together with the sampling procedures. One analytical method is grab sampling followed by analysis by gaschromatography (GC). This procedure was found to give accurate results, provided SO\textsubscript{2} and H\textsubscript{2}O were removed during sampling in order to avoid N\textsubscript{2}O formation in the sample. An evaluation of a continuous infrared N\textsubscript{2}O analyzer shows that it is a useful instrument if measures are taken to eliminate or adjust for interferences from CH\textsubscript{4}, SO\textsubscript{2}, H\textsubscript{2}O, and to a minor extent also from NH\textsubscript{3}. A considerable formation of N\textsubscript{2}O was found when a gas containing SO\textsubscript{2} and NO was scrubbed in a weak acid solution. The sampling program from a variety of combustion systems reveals that N\textsubscript{2}O emissions usually are low (0–5 ppm) from the combustion of pulverized coal. The results from a gas turbine, a laboratory gas‐fired fiber burner, and a domestic oil combustor are also in the very low range, whereas emissions from combustion of straw or wood were slightly higher. Even higher emissions were observed from circulating fluidized bed combustion (CFBC), from which the level of emissions increased with decreasing combustion temperature and increasing...
excess air levels. Sampling inside the CFBC reactor showed that N₂O formation is particularly rapid at the transition from reducing to oxidizing conditions at the secondary air inlet. Pilot plant experiments with the selective non-catalytic reduction of NO by urea or ammonia resulted in a large increase in N₂O emissions during the injection of urea, whereas almost no increase was found during the injection of ammonia.

**General information**

State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Technical University of Denmark
Contributors: Hulgaard, T., Dam-Johansen, K.
Pages: 302-309
Publication date: 1992
Peer-reviewed: Yes

**Publication information**

Journal: Environmental Progress
Volume: 11
Issue number: 4
ISSN (Print): 0278-4491
Ratings:
- BFI (2017): BFI-level 1
- BFI (2016): BFI-level 1
- BFI (2015): BFI-level 1
- BFI (2014): BFI-level 1
- BFI (2013): BFI-level 1
- ISI indexed (2013): ISI indexed yes
- BFI (2012): BFI-level 1
- ISI indexed (2012): ISI indexed yes
- BFI (2011): BFI-level 1
- ISI indexed (2011): ISI indexed yes
- BFI (2010): BFI-level 1
- Web of Science (2010): Impact factor 1.308
- BFI (2009): BFI-level 1
- BFI (2008): BFI-level 1
- Web of Science (2008): Indexed yes
- Web of Science (2003): Indexed yes
Original language: English
DOIs: 10.1002/ep.670110418
Source: Scopus
Source-ID: 84985747313
Research output: Research - peer-review; Journal article – Annual report year: 1992

**NOₓ removal on a coal-fired utility boiler by selective non-catalytic reduction**

A plant for Selective Non-catalytic Reduction (SNR) of NOₓ emissions by NH₃ (ammonia) injection has been designed, installed and successfully tested on a 135 MWe coal-fired utility boiler. The final 2000 hours test was performed with the plant automatically controlled.

The NOₓ level in the untreated flue gas is typically 400–700 ppm, and NH₃ is injected at a molar ratio to NO between 0.6 and 1.8. Through most of the load range 50–70% reduction of the NOₓ emission was achieved.

The temperature window for the process is 850–1050°C, with an optimum at 950°C. In order to minimize the emission of unburnt NH₃, natural gas was added in a molar ratio to NOₓ of about 1 in part of the load range. The plant met a demand of no more than 15 ppm NH₃ in the flue gas.

The research and development work needed for adoption of the SNR-process to coal-firing has been in progress through five years in a cooperation between Alborg Ciserv International, The Technical University of Denmark, and the Danish power plant association ELSAM. The research program included basic laboratory research on the chemical kinetics of the process, pilot scale research on the reducing capacity and emissions of ammonia and urea, testing in laboratory scale and pilot scale of several additives for widening the temperature window and minimizing the NH₃ emission, and development of nozzles for good mixing of NH₃ into the flue gas.

The resulting concept is applicable for NOₓ-removal on several types of boilers.

**General information**

State: Published
High-temperature reaction between sulphur dioxide and limestone-I. Comparison of limestones in two laboratory reactors and a pilot plant

Twenty-three different limestones were studied with respect to their capacity for reaction with sulphur dioxide, and were found to differ markedly. Geologically young limestones have the highest capacity, and geological old limestones the lowest. The presence of ferric oxide affected the sulphur dioxide capacity of limestones adversely, but otherwise no general relationship was observed between chemical composition and sulphur dioxide capacity. A negative correlation exists between the time required for calcination and the sulphur dioxide capacity. Experiments were carried out in three different reactor systems: a laboratory recycle reactor, a laboratory fluidized-bed reactor, and a coal-fired fluidized-bed pilot plant. Qualitatively, the rankings of limestones with respect to sulphur dioxide capacity were identical for the three reactor systems, and laboratory experiments may thus be used for the determination of such a ranking. The pilot plant was less efficient with respect to limestone utilization than the other reactor systems, elutriation from the bed or locally reducing
conditions in the bed being assumed to be the major cause of this difference.
High-temperature reaction between sulphur dioxide and limestone-II. An improved experimental basis for a mathematical model

Most experimental data available in the literature on the high-temperature reaction between sulphur dioxide and limestone have been obtained in the form of an average degree of conversion (sulphation) of the solid limestone particle. Such data have been widely used as a basis for mathematical models of the reaction. It is, however, well known that a sulphated limestone particle is characterized by a highly non-uniform intraparticle conversion profile. Information on the intraparticle reaction is therefore desirable in order to improve the basis for mathematical models. Such information is presented in the following for a limestone constituted of non-porous grains. The product of the sulphation reaction under oxidizing conditions is demonstrated to be anhydrite II, not anhydrite III as commonly assumed in the literature. These two forms of calcium sulphate are of different molar volume, an important parameter in any detailed mathematical model. Pore size distributions have been determined before and after calcination and after sulphation. Calcination causes formation of a micropore structure and development of a bimodal pore size distribution. During sulphation the micropores become filled, or their entrances become blocked, but the macropore structure present in the uncalcined material remains. Intraparticle conversion profiles were determined in sulphated particles by energy-dispersive X-ray analysis. The degree of conversion decreases linearly from the particle surface inwards to a certain distance from the surface where it decreases to zero, forming a sharp front that moves inwards with increasing reaction time.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Contributors: Dam-Johansen, K., Østergaard, K.
Pages: 839-845
Publication date: 1991
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 46
Issue number: 3
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.306
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
Web of Science (2016): Impact factor 2.895
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
Web of Science (2015): Impact factor 2.75
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 2.81 SJR 1.104 SNIP 1.629
Web of Science (2014): Impact factor 2.337
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.95 SJR 1.145 SNIP 1.843
Web of Science (2013): Impact factor 2.613
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 2.77 SJR 1.172 SNIP 1.828
Web of Science (2012): Impact factor 2.386
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 2.8 SJR 1.19 SNIP 1.678
Web of Science (2011): Impact factor 2.431
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.312 SNIP 1.698
Web of Science (2010): Impact factor 2.379
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.289 SNIP 1.742
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.294 SNIP 1.584
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.332 SNIP 1.553
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.305 SNIP 1.563
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.44 SNIP 1.775
Scopus rating (2004): SJR 1.299 SNIP 1.844
Web of Science (2004): Indexed yes
High-temperature reaction between sulphur dioxide and limestone-III. A grain-micrograin model and its verification

A modified grain model of the reaction between calcined chalk, sulphur dioxide and oxygen has been developed, and the model has been verified by comparison with a large volume of experimental data. A chalk particle is constituted of grains that are non-porous in the uncalcined state. The pore volume of calcined chalk is distributed between macropores corresponding to the interstices between grains and micropores formed in the grains during calcination. The porous grains are assumed to be constituted of non-porous micrograins. Mass transfer in the pores takes place by molecular diffusion and Knudsen diffusion, and micrograins react with sulphur dioxide and oxygen according to a shrinking, unreacted-core mechanism. Since calcium sulphate formed by the reaction has a significantly higher molar volume than calcium oxide, micrograins will grow in volume with increasing degree of sulphation, eventually filling the micropores at a degree of sulphation of approximately 50%. Further reaction in the grains takes place according to a shrinking, partially-reacted-core mechanism, accompanied by an increase in grain volume. The only unknown parameters in the model are the tortuosity factor and the diffusion coefficient in the solid product layer encasing micrograins and grains.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Contributors: Dam-Johansen, K., Hansen, P. F., Østergaard, K.
Pages: 847-853
Publication date: 1991
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 46
Issue number: 3
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
Web of Science (2017): Impact factor 3.306
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
Web of Science (2016): Impact factor 2.895
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
Web of Science (2015): Impact factor 2.75
High-temperature reaction between sulphur dioxide and limestone-IV. A discussion of chemical reaction mechanisms and kinetics

A model describing the chemical kinetics of the sulphation of calcium oxide has been developed in terms of elementary chemical reaction mechanisms. The model predicts that the rate-determining reaction at low temperatures is the disproportionation of calcium sulphite and that the rate-determining reaction at high temperatures is the direct oxidation of calcium sulphite and/or the reaction between calcium oxide and sulphur trioxide. The model is in good agreement with the limited amount of experimental measurements of initial rates of the sulphation reaction available in the literature.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, The Hempel Foundation Coatings Science and Technology Centre (CoaST), Technical University of Denmark
Contributors: Dam-Johansen, K., Østergaard, K.
Pages: 855-859
Publication date: 1991
Peer-reviewed: Yes

Publication information
Journal: Chemical Engineering Science
Volume: 46
Issue number: 3
ISSN (Print): 0009-2509
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Impact factor 3.306
Scopus rating (2017): CiteScore 3.44 SJR 1.043 SNIP 1.516
BFI (2016): BFI-level 2
Web of Science (2016): Impact factor 2.895
Scopus rating (2016): CiteScore 3.05 SJR 1.039 SNIP 1.464
BFI (2015): BFI-level 2
Web of Science (2015): Impact factor 2.75
Scopus rating (2015): CiteScore 2.96 SJR 1.022 SNIP 1.589
BFI (2014): BFI-level 2
Web of Science (2014): Indexed yes
Scopus rating (2014): CiteScore 2.81 SJR 1.104 SNIP 1.629
BFI (2013): BFI-level 2
Web of Science (2013): Indexed yes
Scopus rating (2013): CiteScore 2.95 SJR 1.145 SNIP 1.843
BFI (2012): BFI-level 2
Web of Science (2012): Impact factor 2.613
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Web of Science (2011): Indexed yes
Scopus rating (2011): CiteScore 2.77 SJR 1.172 SNIP 1.828
BFI (2010): BFI-level 2
Web of Science (2010): Indexed yes
ISI indexed (2010): ISI indexed yes
BFI (2009): BFI-level 2
Web of Science (2009): Indexed yes
ISI indexed (2009): ISI indexed yes
Influence of additives on selective noncatalytic reduction of nitric oxide with ammonia in circulating fluidized bed boilers

The application of selective noncatalytic reduction of nitric oxide with ammonia in circulating fluidized bed boilers is investigated. Special attention is directed to the use of additives to the ammonia so that the efficiency of the NO reduction at lower temperatures can be increased. Tests under realistic conditions in a research boiler and reaction kinetic calculations show that the type of additives used did not improve the process. On the other hand, it is shown that ammonia injection as such, when employed before the cyclone of the boiler, effectively reduces the NO emission to a level of 20-60 ppm, without significant negative effects such as ammonia bypass and an increased CO emission.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, CHEC Research Centre, Åbo Akademi University, Chalmers University of Technology
Contributors: Leckner, B., Karlsson, M., Dam-Johansen, K., Erik Weinell, C., Kilpinen, P., Hupa, M.
Number of pages: 9
Pages: 2396-2404
Publication date: 1991
Peer-reviewed: Yes

Publication information
Journal: Industrial and Engineering Chemistry Research
Volume: 30
Issue number: 11
ISSN (Print): 0888-5885
Ratings:
BFI (2019): BFI-level 2
Projects:

**Role of Additives on Corrosion Protection of Metals by Organic Coatings**
Lamprakou, Z., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Erik Weinell, C., Supervisor, Department of Chemical and Biochemical Engineering
01/02/2019 → 31/01/2022
Project: PhD

**Chemical Reactor Operation**
Fangel, P., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
01/02/1963 → 24/11/1965
Project: PhD

**Polysilazanes for Coating Applications**
Sønderbæk-Jørgensen, R., PhD Student, Department of Chemical and Biochemical Engineering
Daugaard, A. E., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Skov, A. L., Supervisor, Department of Chemical and Biochemical Engineering
01/12/2018 → 30/11/2021
Project: PhD

**Coating Degradation Detection and Monitoring under Marine Conditions**
Ortie, N. S., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Erik Weinell, C., Supervisor, Department of Chemical and Biochemical Engineering
01/12/2018 → 30/11/2021
Project: PhD

**Computer-Aided Design of Coatings**
Enevist, M., PhD Student, Department of Chemical and Biochemical Engineering
Kontogeorgis, G., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Liang, X., Supervisor, Department of Chemical and Biochemical Engineering
01/09/2018 → 31/08/2021
Project: PhD

**Flame Synthesis of Nano-particles**
Gao, J., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Lin, W., Supervisor, Department of Chemical and Biochemical Engineering
Wu, H., Supervisor, Department of Chemical and Biochemical Engineering
Mechanisms of High Temperature aggomeration in fluidized beds
Zhao, L., PhD Student, Department of Chemical and Biochemical Engineering
Lin, W., Supervisor, Department of Chemical and Biochemical Engineering
Wu, H., Supervisor, Department of Chemical and Biochemical Engineering
Stipendie fra udlandet
15/05/2018 → 14/05/2021
Award relations: Mechanisms of High Temperature aggomeration in fluidized beds
Project: PhD

Structure property relationships in coatings
Juraskova, A., PhD Student, Department of Chemical and Biochemical Engineering
Skov, A. L., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Olsen, S. M., Supervisor, Others
Samfinansieret - Andet
01/02/2018 → 31/01/2021
Award relations: Structure property relationships in coatings
Project: PhD

Coating with inherent sensing functionality based on dielectric elastomers
Krpovic, S., PhD Student, Department of Chemical and Biochemical Engineering
Skov, A. L., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Samfinansieret - Andet
01/02/2018 → 31/01/2021
Award relations: Coating with inherent sensing functionality based on dielectric elastomers
Project: PhD

Continuous Biocatalytic Alkene Hydrogenation
Lindeque, R. M., PhD Student, Department of Chemical and Biochemical Engineering
Woodley, J., Main Supervisor, Department of Chemical and Biochemical Engineering
Krühne, U., Supervisor, Department of Chemical and Biochemical Engineering
Eksternt finansieret virksomhed
01/11/2017 → 31/10/2020
Award relations: Continuous Biocatalytic Alkene Hydrogenation
Project: PhD

Anticorrosive coatings and pigments engineering
Sedaghat Nezhad, S., PhD Student, Department of Chemical and Biochemical Engineering
Kil, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Erik Weinell, C., Supervisor, Department of Chemical and Biochemical Engineering
Samfinansieret - Andet
01/09/2017 → 31/08/2020
Award relations: Anticorrosive coatings and pigments engineering
Project: PhD

Coating interlayer adhesion loss
Wang, T., PhD Student, Department of Chemical and Biochemical Engineering
Kil, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Erik Weinell, C., Supervisor, Department of Chemical and Biochemical Engineering
Samfinansieret - Andet
01/09/2017 → 31/08/2020
Award relations: Coating interlayer adhesion loss
Project: PhD

Alternative liquid fuels in burners optimized for low NOx emissions and high burn out
Cafaggi, G., PhD Student, Department of Chemical and Biochemical Engineering
Jensen, P. A., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Glarborg, P., Supervisor, Department of Chemical and Biochemical Engineering
Fonde
01/01/2017 → 31/12/2019
Award relations: Alternative liquid fuels in burners optimized for low NOx emissions and high burn out
Project: PhD

Novel testing methods for intumescent coating
Zeng, Y., PhD Student, Department of Chemical and Biochemical Engineering
Kiil, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Samfinansierede - Virksomhed
15/10/2016 → 14/10/2019
Award relations: Novel testing methods for intumescent coating
Project: PhD

CFD Simulation of Heterogeneous Reacting Systems
Luo, H., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Wu, H., Supervisor, Department of Chemical and Biochemical Engineering
Samfinansierede - Virksomhed
01/10/2016 → 30/09/2019
Award relations: CFD Simulation of Heterogeneous Reacting Systems
Project: PhD

Fluidized bed combustion of biomass
Ulusoy, B., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Lin, W., Supervisor, Department of Chemical and Biochemical Engineering
Wu, H., Supervisor, Department of Chemical and Biochemical Engineering
Samfinansieret - Andet
01/09/2016 → 31/08/2019
Award relations: Fluidized bed combustion of biomass
Project: PhD

Soddannelse i tårnkedler
Pedersen, K. H., PhD Student, Department of Chemical and Biochemical Engineering
Jensen, A. D., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Examiner, Department of Chemical and Biochemical Engineering
Bech, N., Examiner
Hupa, M. M., Examiner
DTU-lønnet stipendie
12/12/2008 → 12/12/2008
Award relations: Soddannelse i tårnkedler
Project: PhD

Produktion af lægemidler
Christensen, H., PhD Student, Department of Chemical and Biochemical Engineering
Kiil, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Nielsen, O., Supervisor
Gernaey, K. V., Examiner, Department of Chemical and Biochemical Engineering
Buchwald, S. L., Examiner
Dancer, R. J., Examiner
Brændselsfleksible brændere til cement- og mineralindustri
Nørskov, L. K., PhD Student, Risø National Laboratory for Sustainable Energy
Glarborg, P., Supervisor, Department of Chemical and Biochemical Engineering
Jensen, P. A., Supervisor, Department of Chemical and Biochemical Engineering
Larsen, M. B., Supervisor, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Examiner, Department of Chemical and Biochemical Engineering
Brink, A. S., Examiner
Emberger, B., Examiner
ErhvervsPhD-ordningen VTU
01/01/2009 → 17/12/2012
Award relations: Brændselsfleksible brændere til cement- og mineralindustri
Project: PhD

Forbrændingsmekanismer ved udnyttelse af affald som brændsel i cementproduktion
Larsen, M. B., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Supervisor, Department of Chemical and Biochemical Engineering
Glarborg, P., Supervisor, Department of Chemical and Biochemical Engineering
Jensen, L. S., Supervisor, Department of Chemical and Biochemical Engineering
Livbjerg, H., Examiner, Department of Chemical and Biochemical Engineering
Høstgaard-Jensen, J., Examiner
Leckner, B., Examiner
ErhvervsPhD-ordningen VTU
01/10/2003 → 30/04/2007
Award relations: Forbrændingsmekanismer ved udnyttelse af affald som brændsel i cementproduktion
Project: PhD

Rotérovndesign til maksimal brug af alternative brændsler i cement- og mineralindustri
Nielsen, A. R., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Glarborg, P., Supervisor, Department of Chemical and Biochemical Engineering
Larsen, M. B., Supervisor, Department of Chemical and Biochemical Engineering
Clement, K., Examiner, Department of Chemical and Biochemical Engineering
Leckner, B., Examiner
Sander, B., Examiner
ErhvervsPhD-ordningen VTU
01/04/2008 → 08/02/2012
Award relations: Rotérovndesign til maksimal brug af alternative brændsler i cement- og mineralindustri
Project: PhD

Emissioner fra forbrænding af biomasse
Knudsen, J. N., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Jensen, P. A., Supervisor, Department of Chemical and Biochemical Engineering
Lin, W., Supervisor, Department of Chemical and Biochemical Engineering
Livbjerg, H., Examiner, Department of Chemical and Biochemical Engineering
Hupa, M. M., Examiner
Pedersen, L. S., Examiner, Department of Chemical and Biochemical Engineering
Nordisk finansiering
01/04/2001 → 10/01/2005
Award relations: Emissioner fra forbrænding af biomasse
Project: PhD

Cyklon forvarmerdesign med henblik på emissionsbegrænsning i cementindustrien
Hansen, J. P., PhD Student, Department of Chemistry
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Jensen, L. S., Supervisor, Department of Chemical and Biochemical Engineering
Wedel, S., Supervisor, Department of Chemical and Biochemical Engineering
Johnsson, J. E., Examiner, Department of Applied Chemistry
Hansen, P. F. B., Examiner
Hupa, M. M., Examiner
Erhvervsforskerordenen
01/09/2000 → 18/01/2004
Award relations: Cyklon forvarmerdesign med henblik på emissionsbegrænsning i cementindustrien
Project: PhD

Modellering af gipsproducerede røggasafsvovlingsanlæg
Nyggaard, H. G., PhD Student, Department of Chemical and Biochemical Engineering
Johnsson, J. E., Main Supervisor, Department of Applied Chemistry
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Fogh, F., Supervisor
Nørklit Jensen, J., Supervisor
Kil, S., Supervisor, Department of Chemical and Biochemical Engineering
Wedel, S., Examiner, Department of Chemical and Biochemical Engineering
Jensen, F., Examiner
Karlsson, H. T., Examiner
Erhvervsforskerordenen
01/10/1999 → 06/02/2006
Award relations: Modellering af gipsproducerede røggasafsvovlingsanlæg
Project: PhD

Grænseflader i komposite elektroder i fastoxid - brændselsceller/elektrolysatorer
Hansen, K. V., PhD Student, Department of Energy Conversion and Storage
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Bilde-Sørensen, J., Supervisor, Riso National Laboratory for Sustainable Energy
Chorkendorff, I., Supervisor, Department of Physics
Mogensen, M. B., Supervisor, Department of Energy Conversion and Storage
Hansen, P. L., Examiner
Stimming, U., Examiner
Jacobsen, T., Examiner
Nordisk Finansiering-SU
01/06/1999 → 09/09/2002
Award relations: Grænseflader i komposite elektroder i fastoxid - brændselsceller/elektrolysatorer
Project: PhD

Pyrolyse og forbrænding af biomasse
Stenseng, M., PhD Student, Others
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Jensen, A. D., Supervisor, Department of Chemical and Biochemical Engineering
Hansen, P. F. B., Examiner
Mogensen, G., Examiner
Blandet Finansiering-SU
01/06/1997 → 19/09/2001
Award relations: Pyrolyse og forbrænding af biomasse
Project: PhD

Reaktivitet af faste brændsler
Zolin, A., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Jensen, A. D., Supervisor, Department of Chemical and Biochemical Engineering
Hurt, R., Examiner
Pedersen, L. S., Examiner, Department of Chemical and Biochemical Engineering
Rosenberg, P., Examiner
Forskningsrådssstipendium
01/01/1997 → 16/10/2001
Award relations: Reaktivitet af faste brændsler
Project: PhD
Aske. og Belægningsdannelse i Fyringssystemer
Becerra, S. V., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Supervisor, Department of Chemical and Biochemical Engineering
Dockter, B. A., Examiner
Hansen, P. F. B., Examiner
Skrifvars, B., Examiner
DTU-Su Stipendium, Eksperiment
01/08/1996 → 29/09/2001
Award relations: Aske. og Belægningsdannelse i Fyringssystemer
Project: PhD

Belægningsdannelse ved halmtilsatsfyring
Andersen, K. H., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Luxhøj, F., Examiner
Erhvervsforskerordningen
01/05/1995 → 07/01/1999
Award relations: Belægningsdannelse ved halmtilsatsfyring
Project: PhD

Uorganiske metalforbindelser i forbrænding og forgasning
Hansen, L. A., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Mogensen, G., Examiner
Center-Finansieret-SU
01/04/1994 → 09/03/1998
Award relations: Uorganiske metalforbindelser i forbrænding og forgasning
Project: PhD

Uorganiske metalforbindelser i forbrænding og forgasning
Michelsen, H. P., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Blum, H. J. R., Examiner
Sander, B., Examiner
DTU-Su Stipendium, Eksperiment
01/04/1994 → 16/03/1999
Award relations: Uorganiske metalforbindelser i forbrænding og forgasning
Project: PhD

Sporstoffer i forbrændingsprocesser
Jappe Frandsen, F., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Larsen, A. N., Supervisor
Klitgaard, J., Examiner
Gammel ordning u/skema-SU
Award relations: Sporstoffer i forbrændingsprocesser
Project: PhD

Nitrogenkemi under forbrænding
Kristensen, P. G., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Klitgaard, J., Examiner
Gammel Ordning - Blandet Finan
01/10/1991 → 18/12/1995
Award relations: Nitrogenkemi under forbrænding
Project: PhD

Udnyttelse af kul i kulfyrde kraftværker
Hald, P. M., PhD Student, Risø National Laboratory for Sustainable Energy
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering  
Sander, B., Examiner  
Gammel ordning u/skema-SU  
01/05/1991 → 15/11/1994  
Award relations: Udnyttelse af kul i kulfyrede kraftværker  
Project: PhD

Gasfaseraktioners afhængighed af ikke ideal strømning  
Østberg, M., PhD Student, Department of Chemical and Biochemical Engineering  
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering  
Hupa, M. M., Examiner  
Klitgaard, J., Examiner  
Gammel ordning u/skema-SU  
01/02/1990 → 13/06/1996  
Award relations: Gasfaseraktioners afhængighed af ikke ideal strømning  
Project: PhD

Development Reactors  
Svith, C. S., PhD Student, Department of Chemical and Biochemical Engineering  
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering  
Lin, W., Supervisor, Department of Chemical and Biochemical Engineering  
Wu, H., Supervisor, Department of Chemical and Biochemical Engineering  
Samfinansierede - Virksomhed  
15/09/2016 → 14/11/2019  
Award relations: Development Reactors  
Project: PhD

Models for estimation and analyses of emissions from chemical processes and products  
Jhamb, S. V., PhD Student, Department of Chemical and Biochemical Engineering  
Kontogeorgis, G., Main Supervisor, Department of Chemical and Biochemical Engineering  
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering  
Liang, X., Supervisor, Department of Chemical and Biochemical Engineering  
Samfinansierede - Virksomhed  
01/10/2016 → 30/09/2019  
Award relations: Models for estimation and analyses of emissions from chemical processes and products  
Project: PhD

Optimized recycling in an integrated melting furnace for production of stone wool melt  
Schultz-Falk, V., PhD Student, Department of Chemical and Biochemical Engineering  
Jensen, P. A., Main Supervisor, Department of Chemical and Biochemical Engineering  
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering  
Hansen, L. E., Supervisor  
Solvang, M., Supervisor  
Industrial PhD  
01/08/2016 → 13/02/2020  
Award relations: Optimized recycling in an integrated melting furnace for production of stone wool melt  
Project: PhD

Computational Fluid Dynamics (CFD) Study of Bio-Dust Combustion  
Leth-Espensen, A., PhD Student, Department of Chemical and Biochemical Engineering  
Glarborg, P., Main Supervisor, Department of Chemical and Biochemical Engineering  
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering  
Jensen, P. A., Supervisor, Department of Chemical and Biochemical Engineering  
Institut stipendie (DTU)  
01/05/2016 → 30/04/2019  
Award relations: Computational Fluid Dynamics (CFD) Study of Bio-Dust Combustion  
Project: PhD

Surface Characterization of Activated Chalcopyrite Particles  
Karcz, A. P., PhD Student, Department of Chemical and Biochemical Engineering  
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Damø, A. J., Supervisor, Department of Chemical and Biochemical Engineering
Illerup, J. B., Supervisor, Risø National Laboratory for Sustainable Energy
Samfinansieret - Andet
01/05/2016 → 30/04/2019
Award relations: Surface Characterization of Activated Chalcopyrite Particles
Project: PhD

Biomass Particle ignition in mill equipment
Schwarzer, L., PhD Student, Department of Chemical and Biochemical Engineering
Jensen, P. A., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Glarborg, P., Supervisor, Department of Chemical and Biochemical Engineering
Holm, J. K., Supervisor, Department of Mechanical Engineering
Institut stipendie (DTU)
15/12/2015 → 14/03/2019
Award relations: Biomass Particle ignition in mill equipment
Project: PhD

HCI emission from cement plants
Pachitsas, S., PhD Student, Department of Chemical and Biochemical Engineering
Wedel, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Jensen, L. S., Supervisor, Department of Chemical and Biochemical Engineering
Jensen, P. A., Examiner, Department of Chemical and Biochemical Engineering
Pedersen, K. H., Examiner, Department of Chemical and Biochemical Engineering
Yrjas, P. K., Examiner
Samfinansierede - Virksomhed
15/05/2015 → 29/06/2018
Award relations: HCI emission from cement plants
Project: PhD

Thermochemical Conversion of Biomass
Anicic, B., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Lin, W., Supervisor, Department of Chemical and Biochemical Engineering
Wu, H., Supervisor, Department of Chemical and Biochemical Engineering
Erik Weinell, C., Examiner, Department of Chemical and Biochemical Engineering
Li, S., Examiner
Lyu, J., Examiner
Wang, W., Supervisor
Samfinansieret - Andet
01/05/2015 → 30/09/2018
Award relations: Thermochemical Conversion of Biomass
Project: PhD

Burners for Cement Kilns
Pedersen, M. N., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Clausen, S., Supervisor, Department of Chemical and Biochemical Engineering
Jensen, P. A., Supervisor, Department of Chemical and Biochemical Engineering
Jensen, L. S., Supervisor, Department of Chemical and Biochemical Engineering
Christensen, J. M., Examiner, Department of Chemical and Biochemical Engineering
Hansen, L. E., Examiner
Tokheim, L., Examiner
Samfinansierede - Virksomhed
01/03/2015 → 17/09/2018
Award relations: Burners for Cement Kilns
Project: PhD

Multiphase flow and fuel conversion in cement calciner
Nakhaei, M., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Glarborg, P., Supervisor, Department of Chemical and Biochemical Engineering
Grévain, D., Supervisor
Jensen, L. S., Supervisor, Department of Chemical and Biochemical Engineering
Wu, H., Supervisor, Department of Chemical and Biochemical Engineering
Krühne, U., Examiner, Department of Chemical and Biochemical Engineering
Larsen, M. B., Examiner, Department of Chemical and Biochemical Engineering
Leckner, B., Examiner
Samfinansierede - Virksomhed
15/05/2015 → 12/11/2018
Award relations: Multiphase flow and fuel conversion in cement calciner
Project: PhD

Continuous crystallization and filtration of Ective Pharmaceutical Ingredients and Intermediates for pharmaceutical production
Capellades Mendez, G., PhD Student, Department of Chemical and Biochemical Engineering
Kiil, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Christensen, T. V., Supervisor
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Mealy, M. J., Supervisor
Gernaey, K. V., Examiner, Department of Chemical and Biochemical Engineering
Glennon, B., Examiner
Lopez de Diego, H., Examiner
Samfinansierede - Virksomhed
15/09/2014 → 24/11/2017
Award relations: Continuous crystallization and filtration of Ective Pharmaceutical Ingredients and Intermediates for pharmaceutical production
Project: PhD

Protective Coatings in the Ceement and Mineral Industry
Møller, V. B., PhD Student, Department of Chemical and Biochemical Engineering
Kiil, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Frankær, S. M. G., Supervisor, Department of Chemical and Biochemical Engineering
Abildskov, J., Examiner, Department of Chemical and Biochemical Engineering
Paulsen, A. L., Examiner, Risø National Laboratory for Sustainable Energy
Hilt, M., Examiner
Samfinansierede - Virksomhed
15/08/2014 → 14/03/2018
Award relations: Protective Coatings in the Ceement and Mineral Industry
Project: PhD

Flashpyrolyse af Halm in Situ
Bech, N., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Jensen, P. A., Supervisor, Department of Chemical and Biochemical Engineering
Wedel, S., Examiner, Department of Chemical and Biochemical Engineering
Hustad, J. E., Examiner
Madsen, O. H., Examiner
InnovationsPhD
01/09/2004 → 29/08/2008
Award relations: Flashpyrolyse af Halm in Situ
Project: PhD

Reduktion af Nox fra kalcinatorsystemer
Jensen, L. S., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Glarborg, P., Supervisor, Department of Chemical and Biochemical Engineering
Hansen, P. F. B., Examiner
Løvbjerg, H., Examiner, Department of Chemical and Biochemical Engineering
Erhvervsforskerordningen
01/03/1996 → 22/12/1999
Award relations: Reduktion af Nox fra kalcinatorsystemer
Project: PhD
Product recovery from spray dryers
Frey, M., PhD Student, Department of Chemical and Biochemical Engineering
Jensen, A. D., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Johnsson, J. E., Examiner, Department of Applied Chemistry
Seville, J. P. K., Examiner
Lind, L., Examiner
Erhvervsforskerordningen
01/02/1998 → 05/07/2001
Award relations: Product recovery from spray dryers
Project: PhD

Membrane contactor to replace conventional scrubbers
Iversen, S. B., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Barker, V. A., Supervisor, Department of Informatics and Mathematical Modeling
Madsen, R. F., Examiner
Sander, B., Examiner
Akademiet for de Tekniske Videnskaber
01/10/1991 → 28/03/1995
Award relations: Membrane contactor to replace conventional scrubbers
Project: PhD

Efficient and environmentally friendly antifouling paints
Meseguer Yebra, D., PhD Student, Department of Chemical and Biochemical Engineering
Kii, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Erik Weinell, C., Supervisor, Department of Chemical and Biochemical Engineering
Villadsen, J., Examiner, Department of Chemical and Biochemical Engineering
Codolar, S. A., Examiner
Haslbeck, E. G., Examiner
Forskningsrådsfinansiering
01/05/2002 → 30/09/2005
Award relations: Efficient and enviromentally friendly antifouling paints
Project: PhD

Nitrogen chemistry in fluidized bed combustion
Jensen, A. D., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Klitgaard, J., Examiner
DTU-stipendium
01/08/1991 → 09/07/1996
Award relations: Nitrogen chemistry in fluidized bed combustion
Project: PhD

Ristefyring af biomasse
Rejel, H., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Jensen, A. D., Supervisor, Department of Chemical and Biochemical Engineering
Hansen, P. F. B., Examiner
Blandet Finansiering-SU
01/08/1996 → 06/04/2001
Award relations: Ristefyring af biomasse
Project: PhD

Models for Pulverized Coal and Fluidized Bed Combustors
Lans, R. P. V. D., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Glarborg, P., Supervisor, Department of Chemical and Biochemical Engineering
Hupa, M. M., Examiner
Low Nox Burners
Pedersen, L. S., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Bendixen, K., Examiner
Hupa, M. M., Examiner
DTU-Su Stipendium, Eksperiment
01/08/1994 → 21/01/1998
Award relations: Low Nox Burners
Project: PhD

Emission fra cement produktion
Hu, G., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Hansen, J. P., Supervisor, Department of Chemistry
Wedel, S., Supervisor, Department of Chemical and Biochemical Engineering
Olsen, S. M., Supervisor, Others
Kiil, S., Examiner, Department of Chemical and Biochemical Engineering
Hupa, M. M., Examiner
Jensen, L. S., Examiner, Department of Chemical and Biochemical Engineering
Shotløse stipendie
01/02/2004 → 30/04/2007
Award relations: Emission fra cement produktion
Project: PhD

Design of hydrophilic polymers for activated non-fouling coatings
Noguer, A. C., PhD Student, Department of Chemical and Biochemical Engineering
Kiil, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Hvilsted, S., Supervisor, Department of Chemical and Biochemical Engineering
Olsen, S. M., Supervisor, Others
Szabo, P., Examiner, Department of Chemical and Biochemical Engineering
Bressy, C., Examiner
Martínez, E. A., Examiner
Industrial PhD
01/12/2013 → 15/03/2017
Award relations: Design of hydrophilic polymers for activated non-fouling coatings
Project: PhD

Mathematical Modelling of vegetable oil crystallisation
Hjorth, J. L., PhD Student, Department of Chemical and Biochemical Engineering
Kiil, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Leth-Miller, R., Supervisor, Department of Applied Mathematics and Computer Science
Abildskov, J., Examiner, Department of Chemical and Biochemical Engineering
Fløter, E., Examiner
Schafer, O., Examiner
ErhvervsPhD-ordningen VTU
01/05/2011 → 27/08/2014
Award relations: Mathematical Modelling of vegetable oil crystallisation
Project: PhD

Design of continuous reactor systems for API production
Pedersen, M. J., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Kiil, S., Supervisor, Department of Chemical and Biochemical Engineering
Skovby, T., Supervisor
Gernaey, K. V., Examiner, Department of Chemical and Biochemical Engineering
Petersen, H., Examiner
Kappe, O., Examiner  
ErhvervsPhD-ordningen VTU  
01/08/2011 → 17/12/2014  
Award relations: Design of continuous reactor systems for API production  
Project: PhD

Controlled Release of Environmentally Friendly Antifouling Agents from Marine Coatings
Olsen, S. M., PhD Student, Department of Chemical and Biochemical Engineering  
Kiil, S., Main Supervisor, Department of Chemical and Biochemical Engineering  
Pedersen, L. T., Supervisor, Department of Biotechnology  
Woodley, J., Examiner, Department of Chemical and Biochemical Engineering  
Swain, G. W., Examiner  
Erik Weinell, C., Examiner, Department of Chemical and Biochemical Engineering  
ErhvervsPhD-ordningen VTU  
01/11/2005 → 01/04/2009  
Award relations: Controlled Release of Environmentally Friendly Antifouling Agents from Marine Coatings  
Project: PhD

Reactive Separation Technology: Biometric Enzyme Immobilization
Marpani, F. B., PhD Student, Department of Chemical and Biochemical Engineering  
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering  
Christensen, J. M., Examiner, Department of Chemical and Biochemical Engineering  
Jönsson, A., Examiner  
Kontogeorgis, G., Main Supervisor, Department of Chemical and Biochemical Engineering  
Pedersen, L. H., Examiner  
Stipendie fra udlændet  
01/11/2012 → 22/05/2018  
Award relations: Reactive Separation Technology: Biometric Enzyme Immobilization  
Project: PhD

Flash Pyrolysis of Energy Crops
Ibrahim, N., PhD Student, Department of Chemical and Biochemical Engineering  
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering  
Jappe Frandsen, F., Supervisor, Department of Chemical and Biochemical Engineering  
Leckner, B., Examiner  
Liden, G., Examiner  
Hupa, M. M., Examiner  
DTU-lønnet stipendie  
01/10/2005 → 21/12/2010  
Award relations: Flash Pyrolysis of Energy Crops  
Project: PhD

Pre-Treatment (and Enzymatic Hydrolysis) of Ligno-Cellulose
Andric, P., PhD Student, Department of Chemical and Biochemical Engineering  
Jensen, P. A., Main Supervisor, Department of Chemical and Biochemical Engineering  
Meyer, A. S., Supervisor, Department of Biotechnology and Biomedicine  
Villadsen, J., Examiner, Department of Chemical and Biochemical Engineering  
Liden, G., Examiner  
Olsen, H. S., Examiner  
DTU-lønnet stipendie  
01/10/2005 → 21/12/2010  
Award relations: Pre-Treatment (and Enzymatic Hydrolysis) of Ligno-Cellulose  
Project: PhD

Co-Combustion of Fossil Fuels and Waste
Wu, H., PhD Student, Department of Chemical and Biochemical Engineering  
Glarborg, P., Main Supervisor, Department of Chemical and Biochemical Engineering  
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering  
Jappe Frandsen, F., Supervisor, Department of Chemical and Biochemical Engineering  
Leckner, B., Examiner  
Hupa, M. M., Examiner
Hustad, J. E., Examiner
DTU-lønnet stipendie
01/11/2007 → 21/09/2011
Award relations: Co-Combustion of Fossil Fuels and Waste
Project: PhD

Mathematical Modelling of Solid Oxide Fuel Cells
Mogensen, D., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Grunwaldt, J., Supervisor, Department of Chemical and Biochemical Engineering
Hendriksen, P. V., Supervisor, Risø National Laboratory for Sustainable Energy
Nielsen, J. U., Supervisor, Department of Chemistry
Jensen, A. D., Examiner, Department of Chemical and Biochemical Engineering
Stimming, U., Examiner
Sehested, J., Examiner
1/3 DTU-stip, 2/3 FUR/andet
01/11/2007 → 13/04/2011
Award relations: Mathematical Modelling of Solid Oxide Fuel Cells
Project: PhD

Fremstilling af Asymmetriske Membraner ved Deponering af Nano-Partikler
Elmøe, T. D., PhD Student, Department of Chemical and Biochemical Engineering
Grunwaldt, J., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Jonsson, G. E., Examiner, Department of Chemical and Biochemical Engineering
Mädler, L., Examiner
Clausen, B., Examiner
Pratsinis, S. E., Supervisor
DTU-lønnet stipendie
01/03/2005 → 29/08/2008
Award relations: Fremstilling af Asymmetriske Membraner ved Deponering af Nano-Partikler
Project: PhD

Clinker Burning Kinetics and Mechanisms
Telschow, S., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Supervisor, Department of Chemical and Biochemical Engineering
Wedel, S., Supervisor, Department of Chemical and Biochemical Engineering
Jensen, P. A., Examiner, Department of Chemical and Biochemical Engineering
Hupa, M. M., Examiner
Jensen, L. S., Examiner, Department of Chemical and Biochemical Engineering
DTU-lønnet stipendie
01/03/2008 → 24/05/2012
Award relations: Clinker Burning Kinetics and Mechanisms
Project: PhD

Kemisk Produktudvikling - Formulering og karakterisering af enzymgranulater
Jørgensen, K., PhD Student, Department of Chemical and Biochemical Engineering
Jensen, A. D., Main Supervisor, Department of Chemical and Biochemical Engineering
Bach, P., Supervisor
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Szabo, P., Examiner
Hansen, T. T., Examiner
Lee, G., Examiner
DTU-lønnet stipendie
15/02/2002 → 07/11/2005
Award relations: Kemisk Produktudvikling - Formulering og karakterisering af enzymgranulater
Project: PhD

Pre-heater design in cement plant for high energy efficiency and low emissions
Maarup, C., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Processes for Low CO2 Emissions
Pathi, S. K., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Hjuler, K., Supervisor
Illerup, J. B., Supervisor, Department of Chemical and Biochemical Engineering
Lin, W., Supervisor, Department of Chemical and Biochemical Engineering
Kil, S., Examiner, Department of Chemical and Biochemical Engineering
Jensen, L. S., Examiner, Department of Chemical and Biochemical Engineering
Murillo, R., Examiner
Institut stipendie (DTU) Samf.
01/01/2010 → 18/12/2013
Award relations: Processes for Low CO2 Emissions
Project: PhD

Biomass gasification in circulating fluidized beds
Seerup, R., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Lin, W., Supervisor, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Examiner, Department of Chemical and Biochemical Engineering
Larsen, M. B., Examiner, Department of Chemical and Biochemical Engineering
Song, W., Examiner
Offentlig finansiering
01/11/2013 → 20/06/2018
Award relations: Biomass gasification in circulating fluidized beds
Project: PhD

Synthesis and design of Water/wastewater networks
Handani, Z. B., PhD Student, Department of Chemical and Biochemical Engineering
Kontogeorgis, G., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Woodley, J., Examiner, Department of Chemical and Biochemical Engineering
Georgiadis, M. C., Examiner
Mujtaba, I. M., Examiner
Stipendie fra udlandet
01/05/2013 → 31/12/2017
Award relations: Synthesis and design of Water/wastewater networks
Project: PhD

Production, Refining and Utilization of Biomass for Energy Services
Saleh, S. B., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Hansen, B. B., Supervisor, Department of Chemical and Biochemical Engineering
Jensen, P. A., Supervisor, Department of Chemical and Biochemical Engineering
Ahrenfeldt, J., Examiner, Risø National Laboratory for Sustainable Energy
Holm, J. K., Examiner, Department of Mechanical Engineering
Brink, A. S., Examiner
Stipendie fra udlandet
01/01/2010 → 26/02/2014
Award relations: Production, Refining and Utilization of Biomass for Energy Services
Project: PhD
Operational aspects of continuous pharmaceutical production
Mitic, A., PhD Student, Department of Chemical and Biochemical Engineering
Gernaey, K. V., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Skovby, T., Supervisor
Jensen, A. D., Examiner, Department of Chemical and Biochemical Engineering
Aelterman, W., Examiner
Hessel, V., Examiner
1/3 DTU-stip, 2/3 FUR/andet
15/11/2010 → 02/07/2014
Award relations: Operational aspects of continuous pharmaceutical production
Project: PhD

Optimized Production of cement
Rasmussen, M. H., PhD Student, Department of Chemistry
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Illerup, J. B., Supervisor, Department of Chemical and Biochemical Engineering
Pedersen, K. H., Supervisor, Department of Chemical and Biochemical Engineering
Wedel, S., Supervisor, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Examiner, Department of Chemical and Biochemical Engineering
Jensen, L. S., Examiner, Department of Chemical and Biochemical Engineering
Yrjas, P. K., Examiner
1/3 DTU-stip, 2/3 FUR/andet
01/09/2007 → 29/11/2011
Award relations: Optimized Production of cement
Project: PhD

Design and testing of robust and efficient fire-retardant coatings
Nørgaard, K. P., PhD Student, Department of Chemical and Biochemical Engineering
Kil, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Examiner, Department of Chemical and Biochemical Engineering
Deters, D. C., Examiner
Giovanni, C., Examiner
1/3 DTU-stip, 2/3 FUR/andet
01/01/2011 → 28/05/2014
Award relations: Design and testing of robust and efficient fire-retardant coatings
Project: PhD

Characterization and quantification of deposits build up and removal in straw suspension fired boilers
Shafique Bashir, M., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Supervisor, Department of Chemical and Biochemical Engineering
Jensen, P. A., Supervisor, Department of Chemical and Biochemical Engineering
Wedel, S., Supervisor, Department of Chemical and Biochemical Engineering
Glarborg, P., Examiner, Department of Chemical and Biochemical Engineering
Jensen, J. P., Examiner, Department of Chemical and Biochemical Engineering
Tran, H., Examiner
Offentlig finansiering
01/09/2008 → 30/09/2012
Award relations: Characterization and quantification of deposits build up and removal in straw suspension fired boilers
Project: PhD

Fluid dynamics and reactions in high-temperature gas-solid Energy Processes
Ahli Gharamaleki, M., PhD Student, National Food Institute
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Lin, W., Supervisor, Department of Chemical and Biochemical Engineering
Jensen, A. D., Examiner, Department of Chemical and Biochemical Engineering
Jensen, B. H., Examiner
Song, W., Examiner
Offentlig finansiering
15/12/2013 → 22/05/2018
Award relations: Fluid dynamics and reactions in high-temperature gas-solid Energy Processes
Wind Turbine Blade Coatings with Anti-Erosion Properties
Zhang, S., PhD Student, Department of Chemical and Biochemical Engineering
Kill, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Sørensen, P. A., Supervisor, Risø National Laboratory for Sustainable Energy
Szabo, P., Examiner, Department of Chemical and Biochemical Engineering
Stack, M., Examiner
Sylvestre Nielsen, K., Examiner
Institut, samfinansiering
01/09/2011 → 26/11/2014
Award relations: Wind Turbine Blade Coatings with Anti-Erosion Properties
Project: PhD

Fuel Efficiency and Fouling Control Coatings in Maritime Transport
Lindholdt, A., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Kill, S., Supervisor, Department of Chemical and Biochemical Engineering
Olsen, S. M., Supervisor, Others
Meseguer Yebrar, D., Supervisor, Department of Chemical and Biochemical Engineering
Dame, A. J., Examiner, Department of Chemical and Biochemical Engineering
Hoffmann, M., Examiner
Swain, G. W., Examiner
Institut, samfinansiering
01/12/2011 → 30/09/2015
Award relations: Fuel Efficiency and Fouling Control Coatings in Maritime Transport
Project: PhD

Treatment of Lignin and Waste Residues by Flash Pyrolysis
Trinh, N. T., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Jensen, P. A., Supervisor, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Examiner, Department of Chemical and Biochemical Engineering
Jensen, L. S., Examiner, Department of Chemical and Biochemical Engineering
Splieothoff, H., Examiner
1/3 DTU-stip, 2/3 FUR/andet
01/01/2010 → 30/09/2013
Award relations: Treatment of Lignin and Waste Residues by Flash Pyrolysis
Project: PhD

Gas-Solid reactions and reactor systems
Azizaddini, S., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Jensen, P. A., Supervisor, Department of Chemical and Biochemical Engineering
Lin, W., Supervisor, Department of Chemical and Biochemical Engineering
Henriksen, U. B., Examiner, Department of Chemical and Biochemical Engineering
Li, S., Examiner
Erik Weinell, C., Examiner, Department of Chemical and Biochemical Engineering
1/3 DTU-stip, 2/3 FUR/andet
01/12/2012 → 26/05/2016
Award relations: Gas-Solid reactions and reactor systems
Project: PhD

Self-Healing anticorrosive coatings
Nesterova, T., PhD Student, Department of Chemical and Biochemical Engineering
Kill, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Pedersen, L. T., Supervisor, Department of Biotechnology
Daugaard, A. E., Examiner, Department of Chemical and Biochemical Engineering
Zwaag, S. V. D., Examiner
Rasmussen, S. N., Examiner
Alternative Fuels in Cement Production
Cortada Mut, M. D. M., PhD Student, Department of Chemical and Biochemical Engineering
Glarborg, P., Supervisor, Department of Chemical and Biochemical Engineering
Nørskov, L. K., Supervisor, Department of Chemical and Biochemical Engineering
Illerup, J. B., Examiner, Department of Chemical and Biochemical Engineering
Schäfer, S., Examiner
Hupa, M. M., Examiner
1/3 DTU-stip, 2/3 FUR/andet
01/09/2011 → 17/12/2014
Award relations: Alternative Fuels in Cement Production
Project: PhD

High-Performance Anticorrosive Coatings
Serensen, P. A., PhD Student, Risø National Laboratory for Sustainable Energy
Kill, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Erik Weinell, C., Supervisor, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Examiner, Department of Chemical and Biochemical Engineering
Gelling, V. J., Examiner
Serensen, O. B., Examiner
DTU-lønned stipendie
01/02/2007 → 04/06/2010
Award relations: High-Performance Anticorrosive Coatings
Project: PhD

Separation of Chiral Active Pharmaceutical Ingredients: A First Step Towards Continuous Preferential Crystallization in the Pharmaceutical Industry
Chaaban, J. H., PhD Student, Department of Chemical and Biochemical Engineering
Kill, S., Main Supervisor, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Supervisor, Department of Chemical and Biochemical Engineering
Skovby, T., Supervisor
Gernaey, K. V., Examiner, Department of Chemical and Biochemical Engineering
Christensen, T. V., Examiner
Kalman Nagy, Z., Examiner
1/3 DTU-stip, 2/3 FUR/andet
01/01/2010 → 24/06/2013
Award relations: Separation of Chiral Active Pharmaceutical Ingredients: A First Step Towards Continuous Preferential Crystallization in the Pharmaceutical Industry
Project: PhD

Emission af kulbrinter fra lean.brun gasmotorer
Bendtsen, A. B., PhD Student, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Main Supervisor, Department of Chemical and Biochemical Engineering
Glarborg, P., Supervisor, Department of Chemical and Biochemical Engineering
Martens, H., Examiner, Department of Biotechnology
Kandidatstipendium ansat på DT
01/08/1996 → 19/10/1999
Award relations: Emission af kulbrinter fra lean.brun gasmotorer
Project: PhD

CHEC
CHEC is an acronym for the fundamental and applied research programme on Combustion and Harmful Emission Control. CHEC's main areas of expertise are industrial high-temperature processes, formation and removal of pollutants, particulate solids (characterisation, reactivity and dynamics). Within these areas the objectives are to educate scientists and engineers, to gain new fundamental information on the subjects, to assist industry and public authorities in the selection, development, design and operation of processes in order to improve efficiencies and in order to avoid or minimise harmful emissions, to catalyse international cooperation between Danish companies and Danish and foreign
referred to research organisations.

Dam-Johansen, K., Project Manager, Department of Chemical and Biochemical Engineering
Ambrosius, M., Project Participant, Department of Chemical and Biochemical Engineering
Bank, L. H., Project Participant, Department of Chemical and Biochemical Engineering
Becerra, S. V., Project Participant, Department of Chemical and Biochemical Engineering
Cenni, R., Project Participant, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Project Participant, Department of Chemical and Biochemical Engineering
Frandsen, J., Project Participant, Department of Chemical and Biochemical Engineering
Glarborg, P., Project Participant, Department of Chemical and Biochemical Engineering
Hansen, E. M. T. H., Project Participant, Department of Chemical and Biochemical Engineering
Hansen, J., Project Participant, Department of Chemical and Biochemical Engineering
Henriksen, A., Project Participant, Department of Chemical and Biochemical Engineering
Jensen, A. D., Project Participant, Department of Chemical and Biochemical Engineering
Jensen, L. S., Project Participant, Department of Chemical and Biochemical Engineering
Jensen, P. A., Project Participant, Department of Chemical and Biochemical Engineering
Jørgensen, T. L., Project Participant, Department of Chemical and Biochemical Engineering
Lans, R. P. V. D., Project Participant, Department of Chemical and Biochemical Engineering
Lin, W., Project Participant, Department of Chemical and Biochemical Engineering
Stenseng, M., Project Participant, Department of Chemical and Biochemical Engineering
Wolfe, T., Project Participant, Department of Chemical and Biochemical Engineering
Zolin, A., Project Participant, Department of Chemical and Biochemical Engineering
Degn, L., Project Participant, Department of Chemical and Biochemical Engineering
Kill, S., Project Participant, Department of Chemical and Biochemical Engineering
Kristensen, K. A., Project Participant, Department of Chemical and Biochemical Engineering
Michelsen, H. P., Project Participant, Department of Chemical and Biochemical Engineering
Olsen, S. M., Project Participant, Department of Chemical and Biochemical Engineering
Skjøth-Rasmussen, M. S., Project Participant, Department of Chemical and Biochemical Engineering
Rejel, H., Project Participant, Department of Chemical and Biochemical Engineering
Schmidt, L. M., Project Participant, Department of Chemical and Biochemical Engineering
Frey, M., Project Participant, Department of Chemical and Biochemical Engineering
Kristensen, L., Project Participant, Department of Chemical and Biochemical Engineering
Nygaard, H. G., Project Participant, Department of Chemical and Biochemical Engineering
Leth-Miller, R., Project Participant, Department of Chemical and Biochemical Engineering
Sullivan, N. P., Project Participant, Department of Chemical and Biochemical Engineering
Bendtsen, A. B., Project Participant, Department of Chemical and Biochemical Engineering
Johnsson, J. E., Project Participant, Department of Applied Chemistry

Ukendt: DKK12,000,000.00

10/01/1986 → …


Award relations: CHEC

Project: Research

Efficient and Clean Use of Biomass for Power and Heat Production. Phase I.

Pretreatment of biomass fuels for power production. Fluid bed combustion of biomass. Ash formation and emission of trace compounds. Formation and sintering of deposits.

Dam-Johansen, K., Project Manager, Department of Chemical and Biochemical Engineering
Andersen, K. H., Project Participant, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Project Participant, Department of Chemical and Biochemical Engineering
Hansen, E. M. T. H., Project Participant, Department of Chemical and Biochemical Engineering
Hansen, J., Project Participant, Department of Chemical and Biochemical Engineering
Bank, L. H., Project Participant, Department of Chemical and Biochemical Engineering
Hansen, L. A., Project Participant, Department of Chemical and Biochemical Engineering
Jensen, P. A., Project Participant, Department of Chemical and Biochemical Engineering
Lin, W., Project Participant, Department of Chemical and Biochemical Engineering
Michelsen, H. P., Project Participant, Department of Chemical and Biochemical Engineering
Wolfe, T., Project Participant, Department of Chemical and Biochemical Engineering
Jørgensen, T. L., Project Participant, Department of Chemical and Biochemical Engineering
Johnsson, J. E., Project Participant, Department of Applied Chemistry

Ukendt: DKK5,500,000.00, Ukendt: DKK4,100,000.00

01/01/1996 → 31/12/1998
Award relations: Efficient and Clean Use of Biomass for Power and Heat Production. Phase I.
Project: Research

Combustion and Harmful Emission Control
Dam-Johansen, K., Project Manager, Department of Chemical and Biochemical Engineering
Jappe Frandsen, F., Project Participant, Department of Chemical and Biochemical Engineering
Glarborg, P., Project Participant, Department of Chemical and Biochemical Engineering
Jensen, A. D., Project Participant, Department of Chemical and Biochemical Engineering
Hansen, J., Project Participant, Department of Chemical and Biochemical Engineering
Bank, L. H., Project Participant, Department of Chemical and Biochemical Engineering
Wolfe, T., Project Participant, Department of Chemical and Biochemical Engineering
Johnsson, J. E., Project Participant, Department of Applied Chemistry
Ukendt: DKK10,000,000.00
01/01/1993 → 31/12/1997
Award relations: Combustion and Harmful Emission Control
Project: Research

Lean Burn Engines - Emission Reduction.
Dam-Johansen, K., Project Manager, Department of Chemical and Biochemical Engineering
Bendtsen, A. B., Project Participant, Department of Chemical and Biochemical Engineering
Glarborg, P., Project Participant, Department of Chemical and Biochemical Engineering
Hansen, J., Project Participant, Department of Chemical and Biochemical Engineering
Ukendt: DKK1,400,000.00
01/01/1996 → 31/12/1998
Collaborators: Danish Gas Technology Centre A/S
Award relations: Lean Burn Engines - Emission Reduction.
Project: Research

Low Temperature Nitrogen Chemistry
An experimental and theoretical study of the reburning and advanced reburning processes for nitrogen oxide emission control is undertaken for the 1000-1500 K range.
Glarborg, P., Project Manager, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Project Participant, Department of Chemical and Biochemical Engineering
Hansen, J., Project Participant, Department of Chemical and Biochemical Engineering
Ukendt: DKK450,000.00, Ukendt: DKK1,000,000.00
01/07/1993 → 30/06/1996
Collaborators: Danish Gas Technology Centre A/S
Award relations: Low Temperature Nitrogen Chemistry, Low Temperature Nitrogen Chemistry
Project: Research

Multichannel Reactions and Kinetic Modeling of Combustion Processes
The goal is to provide improved kinetic mechanisms for combustion processes involving complex multichannel reactions. Emphasis is put on aromatics oxidation chemistry.
Glarborg, P., Project Manager, Department of Chemical and Biochemical Engineering
Dam-Johansen, K., Project Participant, Department of Chemical and Biochemical Engineering
Hansen, J., Project Participant, Department of Chemical and Biochemical Engineering
Ukendt: DKK300,000.00
01/08/1994 → 01/08/1997
Collaborators: University of Zaragoza
Award relations: Multichannel Reactions and Kinetic Modeling of Combustion Processes
Project: Research

Activities:
Influence of fuel properties on NOx emission in fluidized bed combustion of biomass
Period: 27 Oct 2018
Burak Ulusoy (Speaker)
Hao Wu (Other)
Weigang Lin (Other)
Peter Glarborg (Other)
Kim Dam-Johansen (Other)
CHEC Research Centre
Department of Chemical and Biochemical Engineering
The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Degree of recognition: International
Documents:
Abstract 6-ISGA Burak Ulusoy

Related external organisation
Sixth International Symposium on Gasification and its Application
Chengdu, China
Activity: Talks and presentations › Conference presentations

Modelling Thermal Runaway of Pulverized Biomass
Period: 7 Sep 2018
Lars Schwarzer (Speaker)
Peter Arendt Jensen (Other)
Peter Glarborg (Other)
Jens Kai Holm (Other)
Kim Dam-Johansen (Other)
Department of Chemical and Biochemical Engineering
CHEC Research Centre
The Hempel Foundation Coatings Science and Technology Centre (CoaST)
Degree of recognition: International
Documents:
2018-09-07_PSN_flattened
Links:
https://meeting-agh.wixsite.com/psn2018 (Conference website)

Related event
Joint meeting of the Polish and Scandinavian-Nordic Sections of the Combustion Institute
06/09/2018 → 07/09/2018
Krakow, Poland
Activity: Talks and presentations › Conference presentations

Reaction kinetics for biomass self-ignition at 150–230°C
Period: 29 Jul 2018 → 3 Aug 2018
Lars Schwarzer (Other)
Peter Arendt Jensen (Other)
Peter Glarborg (Other)
Jens Kai Holm (Other)
Kim Dam-Johansen (Other)
Department of Chemical and Biochemical Engineering
CHEC Research Centre
Description
Poster
Degree of recognition: International
Documents:
2018-07-18_Poster
Links:
http://www.combustionsymposia.org/2018/home (Conference website)

Related event
37th International Symposium on Combustion
29/07/2018 → 03/08/2018
Dublin, Ireland
Activity: Talks and presentations › Conference presentations

Reactivity of sewage sludge, RDF, and straw chars towards NO
Period: 2018
Burak Ulusoy (Speaker)
Hao Wu (Other)
Weigang Lin (Other)
Oskar Karlström (Other)
Songgeng Li (Other)
Wenli Song (Other)
Peter Glarborg (Other)
Kim Dam-Johansen (Other)
CHEC Research Centre
Department of Chemical and Biochemical Engineering
The Hempel Foundation Coatings Science and Technology Centre (CoaST)

Description
Work in progress poster
Documents:
CI_poster_Burak Ulusoy

Related external organisation
37th International Symposium on Combustion
Dublin, Ireland
Activity: Talks and presentations › Conference presentations

Camera Measurements in Cement Kilns – Impact of Alternative Fuels on Kiln Flames
Period: 10 Oct 2017 → 11 Oct 2017
Morten Nedergaard Pedersen (Guest lecturer)
Mads Nielsen (Guest lecturer)
Sønnik Clausen (Guest lecturer)
Peter Arendt Jensen (Guest lecturer)
Lars Skaarup Jensen (Guest lecturer)
Kim Dam-Johansen (Guest lecturer)
Department of Chemical and Biochemical Engineering
CHEC Research Centre
The Hempel Foundation Coatings Science and Technology Centre (CoaST)

Description
Presentation and extended abstract given at Nordic Flame Days 2017
Related event

Nordic Flame Days
10/10/2017 → 11/10/2017
Stockholm, Sweden
Activity: Talks and presentations › Conference presentations