In 2014, the partners in the Danish Underground Consortium (DUC) entered into an agreement on the financing of the Danish Hydrocarbon Research and Technology Centre (DHRTC), which has been established at and is operated from Technical University of Denmark (DTU).

For DHRTC, the aim is to demonstrate how the recovery of oil and gas can be increased in the Danish part of the North Sea on a commercial basis. Specifically, the aim is to demonstrate an increased recovery of oil and gas of 100 MMBOE in 2020. The centre's work involves close collaboration between research and engineering on coming up with innovative solutions to the challenges in the North Sea. This is done through research and partnerships across universities and in interaction with the industry.

Permanently based at DTU, the team is already busily involved in the collaboration with the partner institutions, University of Copenhagen, Aarhus University, Aalborg University and the Geological Survey of Greenland and Denmark (GEUS). In addition, efforts are being made to establish cross-disciplinary partnerships with foreign institutions and private enterprises with a view to conducting research into and developing new technologies for recovering a larger share of Denmark's oil and gas from the North Sea.

DHRTC is a global centre from which researchers can access important data and knowledge about the oil fields, and our research programmes are orchestrated from the centre in partnership with research groups from our partner institutions. The aim of DHRTC at DTU is to ensure that all our efforts are finely coordinated across fields of research and professions, across departmental boundaries and—in the long term—across national borders as well.

The aim over the next four years is to identify and develop a number of large demonstration models, each addressing a potential for increasing Danish oil recovery and demonstrating how much oil and gas the models will be able to deliver.

Organisational unit: Center

Publications:

An integrated experimental approach to quantify the oil recovery potential of seawater and low-salinity seawater injection in North Sea chalk oil reservoirs

In this study, the oil recovery potential of seawater (SW), SW with different ion compositions, low-salinity seawater (LSSW), and formation water (FW), is investigated, using chalk reservoir cores and crude oil from the North Sea. Furthermore, the impact of temperature on SW flooding performance is addressed. A series of flooding experiments were conducted at reservoir conditions (2800 psi and 60 °C), followed by spontaneous imbibition tests. Secondary SW and FW flooding led to the same oil recovery. Tertiary SW injections, performed after secondary FW flooding and secondary LSSW injection, did not lead to any extra oil recovery at 60 °C. Injecting SW at 100 °C did not lead to additional recovery either. Spiking the SO₄⁻² content of SW by four times, at 60 °C, did not show any additional oil production as well as increasing the concentration of Ca²⁺ and the Ca²⁺/Mg²⁺ ratio at 60 °C. Conversely, tertiary LSSW injection, after secondary SW
injection, led to 2.5% OOIP additional oil recovery. More importantly, secondary LSSW injection, compared to the secondary SW and FW injection, led to around 8% OOIP extra oil recovery. Consistently, the results of the imbibition test showed the same trend: tertiary LSSW imbibition, after secondary SW imbibition, led to 4.25% OOIP extra oil recovery. This study, through employing chalk reservoir cores and crude oil, reveals that LSSW flooding in examples of silica containing chalk reservoirs in the North Sea, has a better oil recovery potential compared to both SW and FW flooding. This is in contrast to other published results as it will be discussed in the paper.

**General information**
State: Published
Organisations: Centre for oil and gas – DTU
Authors: Seyyedi, M. (Intern), Tagliaferri, S. (Intern), Abatzis, J. (Intern), Nielsen, S. M. (Intern)
Pages: 267-278
Publication date: 2018
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Fuel
Volume: 232
ISSN (Print): 0016-2361
Ratings:
  - 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): Indexed yes
  - BFI (2016): BFI-level 2
  - Scopus rating (2016): CiteScore 4.9 SJR 1.736 SNIP 2.207
  - Web of Science (2016): Indexed yes
  - BFI (2015): BFI-level 2
  - Scopus rating (2015): SJR 1.781 SNIP 2.123 CiteScore 4.46
  - Web of Science (2015): Indexed yes
  - BFI (2014): BFI-level 2
  - Scopus rating (2014): SJR 1.634 SNIP 2.294 CiteScore 4.14
  - Web of Science (2014): Indexed yes
  - BFI (2013): BFI-level 2
  - Scopus rating (2013): SJR 1.762 SNIP 2.544 CiteScore 4.31
  - ISI indexed (2013): ISI indexed yes
  - Web of Science (2013): Indexed yes
  - BFI (2012): BFI-level 2
  - Scopus rating (2012): SJR 1.813 SNIP 2.425 CiteScore 3.99
  - ISI indexed (2012): ISI indexed yes
  - Web of Science (2012): Indexed yes
  - BFI (2011): BFI-level 2
  - Scopus rating (2011): SJR 2.041 SNIP 2.423 CiteScore 4.1
  - 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): 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
A Numerical Study of Fractured Reservoirs' Productivity Behavior through Coupled Hydromechanical Model

In this study, we develop a state-of-the-art coupled hydromechanical model that captures the spatial and temporal evolution of fractures' aperture. Subsequently, a set of numerical experiments, which considers coupled hydromechanics features, is designed to investigate an inflow performance relationship of fractured reservoirs. In this work, we construct an inflow performance relationship based on multi-rate test concept. Fracture geometry (i.e., different sets of fractures), initial pressure, stresses in horizontal directions, deformable parameters and matrix permeability are utilised to investigate factors that affect productivity behaviour of the system. Our study shows that the inversion of productivity index takes either a quadratic or linear form depending on a permeability contrast between fractures and matrix. Furthermore, quadratic coefficients depend on all the investigated factors. However, the contrast between the magnitude of second- and first-order coefficients mainly depends on the contrast between matrix and fractures' conductivity or permeability. Hence, we conclude that deliverability reduction due to reservoir depletion in fractured reservoirs becomes more severe when the contrast between matrix and fractures' conductivity grows.

General information
State: Published
Organisations: Centre for oil and gas – DTU, Department of Applied Mathematics and Computer Science
Authors: Kadeethum, T. (Intern), Jahanbani Veshareh, M. (Intern), Salimzadeh, S. (Intern), Nick, H. (Intern)
Number of pages: 5
Publication date: 2018

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Main Research Area: Technical/natural sciences
Conference: 80th EAGE Conference & Exhibition 2018 , Copenhagen, Denmark, 11/06/2018 - 11/06/2018
Source: PublicationPreSubmission
Source-ID: 147877318
Publication: Research - peer-review › Article in proceedings – Annual report year: 2018

A three-dimensional coupled thermo-hydro-mechanical model for deformable fractured geothermal systems
A fully coupled thermal-hydraulic-mechanical (THM) finite element model is presented for fractured geothermal reservoirs. Fractures are modelled as surface discontinuities within a three-dimensional matrix. Non-isothermal flow through the rock matrix and fractures are defined and coupled to a mechanical deformation model. A robust contact model is utilised to resolve the contact tractions between opposing fracture surfaces under THM loadings. A numerical model has been developed using the standard Galerkin method. Quadratic tetrahedral and triangular elements are used for spatial discretisation. The model has been validated against several analytical solutions, and applied to study the effects of the deformable fractures on the injection of cold water in fractured geothermal systems.

Results show that the creation of flow channeling due to the thermal volumetric contraction of the rock matrix is very likely. The fluid exchanges heat with the rock matrix, which results in cooling down of the matrix, and subsequent volumetric deformation. The cooling down of the rock matrix around a fracture reduces the contact stress on the fracture surfaces, and increases the fracture aperture. Stress redistribution reduces the aperture, as the area with lower contact stress on the fracture expands. Stress redistribution reduces the likelihood of fracture propagation under pure opening mode, while the expansion of the area with lower contact stress may increase the likelihood of shear fracturing.
Austenite reversion in low-carbon martensitic stainless steels – a CALPHAD-assisted review
Low-carbon martensitic stainless steels with 11.5–16 wt-% Cr and <0.07 wt-% C are characterised by high corrosion resistance, strength, ductility and impact toughness, obtained by formation of fine-grained reverted austenite from lath martensite upon inter-critical annealing. The review treats the mechanisms governing the formation and stabilisation of reverted austenite and is assisted by the computation of phase equilibria. Literature data on Cr and Ni concentrations of the reverted austenite/martensite dual-phase microstructure are assessed with respect to predicted concentrations. Reasonable agreement was found for concentrations in martensite. Systematic excess of Cr in austenite of approx. 2 wt-% relative to calculations was suspected to originate from the growth of M23C6 with a coherent interface to austenite. Within large scatter, measured values of Ni in austenite were on average 2 wt-% below predictions. Complex equilibration of the microstructure and experimental error are discussed as possible origins of the discrepancies.

General information
State: Accepted/In press
Organisations: Centre for oil and gas – DTU, Department of Mechanical Engineering, Materials and Surface Engineering
Authors: Niessen, F. (Intern)
Number of pages: 14
Publication date: 2018
Main Research Area: Technical/natural sciences

Publication information
Journal: Materials Science and Technology
ISSN (Print): 0267-0836
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.89 SJR 0.889 SNIP 1.004
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.43 SJR 0.833 SNIP 0.859
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.623 SNIP 0.774 CiteScore 1.1
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.775 SNIP 0.996 CiteScore 1.1
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.631 SNIP 0.846 CiteScore 0.92
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.683 SNIP 0.965 CiteScore 0.86
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.667 SNIP 1.047 CiteScore 0.94
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.635 SNIP 0.776
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
A Water Treatment Case Study for Quantifying Model Performance with Multilevel Flow Modeling

Decision support systems are a key focus of research on developing control rooms to aid operators in making reliable decisions, and reducing incidents caused by human errors. For this purpose, models of complex systems can be developed to diagnose causes or consequences for specific alarms. Models applied in safety systems of complex and safety-critical systems require rigorous and reliable model building and testing. Multilevel Flow Modelling is a qualitative and discrete method for diagnosing faults and has previously only been validated by subjective and qualitative means. To ensure reliability during operation, this work aims to synthesize a procedure to measure model performance according to diagnostic requirements. A simple procedure is proposed for validating and evaluating the concept of Multilevel Flow Modelling. For this purpose, expert statements, dynamic process simulations, and pilot plant experiments are used for validation of simple Multilevel Flow Modelling models of a hydrocyclone unit for oil removal from produced water.

General information
State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Chemical and Biochemical Engineering, PROSYS - Process and Systems Engineering Centre, Centre for oil and gas – DTU, Aalborg University
Authors: Nielsen, E. K. (Intern), Bram, M. V. (Ekstern), Frutiger, J. (Intern), Sin, G. (Intern), Lind, M. (Intern)
Pages: 532-541
Publication date: 2018
Main Research Area: Technical/natural sciences

Publication information
Journal: Nuclear Engineering and Technology
Volume: 50
Issue number: 4
ISSN (Print): 1738-5733
Ratings:
Web of Science (2018): Indexed yes
Scopus rating (2017): SJR 0.854 SNIP 1.477 CiteScore 1.66
Web of Science (2017): Indexed Yes
Scopus rating (2016): CiteScore 1.27 SJR 0.838 SNIP 1.459
Scopus rating (2015): SJR 0.901 SNIP 1.128 CiteScore 1.09
Scopus rating (2014): SJR 0.969 SNIP 1.582 CiteScore 0.93
A dynamic plantwide model was developed for the synthesis of the Active pharmaceutical Ingredient (API) ibuprofen, following the Hoescht synthesis process. The kinetic parameters, reagents, products and by-products of the different reactions were adapted from literature, and the different process operations integrated until the end process, crystallization and isolation of the ibuprofen crystals. The dynamic model simulations were validated against available measurements from literature and then used as enabling tool to analyze the robustness of design space. To this end, sensitivity of the design space towards input disturbances and process uncertainties (from physical and model parameters) is studied using Monte Carlo simulations. The results quantify the uncertainty of the quality of product attributes, with particular focus on crystal size distribution and ibuprofen crystalized. The ranking of the most influential parameters on the chosen quality attributes is presented, with crystal growth and water concentration being the most influential ones. The total amount of saturated solvent, which propagates from upstream processes, has been shown to highly influence the total mass of crystal produced, and the target specifications for the API as well. This dynamic plantwide modeling coupled with Monte Carlo simulations is valuable to improve design and optimization of pharmaceutical processes at early stages, especially to bottleneck the design space against a range of uncertainties and disturbances.
Heat Recovery from Multiple-Fracture Enhanced Geothermal Systems: The Effect of Thermoelastic Fracture Interactions

This study investigates the effect of thermoelastic interactions between multiple parallel fractures on energy production from a multiple-fracture enhanced geothermal system. A coupled thermo-hydro-mechanical finite element model has been developed that accounts for non-isothermal fluid flow within the fractures, conductive heat transfer in the rock matrix, and the mechanical deformation of the matrix. The model results show that the matrix deformation significantly increases the interactions between the two adjacent fractures. Matrix contraction due to the cooling of the matrix increases the fracture aperture in the adjacent fracture, and facilitates the creation of favourable flow pathways between the injection and production wells. These flow paths reduce the energy production from the system. The effects of fracture spacing, reservoir temperature gradient and mechanical properties of the rock matrix on the production temperature and the net production energy are investigated. It is shown that the spacing calculated based on the assumption of rigid matrix (constant uniform aperture) are too small, and in order to account for the thermoelastic interactions, the spacing between fractures should be further increased to maximise the net energy production from the system. Otherwise, the multiple-fracture system fails to improve the energy recovery from the geothermal reservoir, as initially intended.
In-situ analysis of redistribution of carbon and nitrogen during tempering of low interstitial martensitic stainless steel

The redistribution of C and N during tempering of X4CrNiMo16-5-1 martensitic stainless steel containing 0.034 wt% C and 0.032 wt% N was studied using in-situ synchrotron X-ray diffraction (XRD) and atom probe tomography (APT). The unit cell volume of martensite decreased continuously during tempering. APT showed that this volume decrease is accounted entirely for by segregation of the interstitial atoms, implying that in low interstitial martensitic stainless steel stress relaxation only contributes negligibly to changes in the martensite unit cell volume.

General information
State: Published
Organisations: Department of Mechanical Engineering, Materials and Surface Engineering, Centre for oil and gas – DTU, INSA Rouen
Authors: Niessen, F. (Intern), Villa, M. (Intern), Danoix, F. (Ekstern), Hald, J. (Intern), Somers, M. A. (Intern)
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Main Research Area: Technical/natural sciences

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Journal: Scripta Materialia
Volume: 154
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BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.19 SJR 1.923 SNIP 1.855
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.71 SJR 1.884 SNIP 1.737
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.259 SNIP 1.841 CiteScore 3.54
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.65 SNIP 2.035 CiteScore 3.55
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.323 SNIP 1.946 CiteScore 3.19
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.292 SNIP 1.996 CiteScore 3.01
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.314 SNIP 2.082 CiteScore 3.21
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.427 SNIP 2.117
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.569 SNIP 1.999
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 2.607 SNIP 2.108
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.216 SNIP 2.157
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 2.079 SNIP 1.899
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.877 SNIP 1.885
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.584 SNIP 1.679
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.622 SNIP 1.687
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.603 SNIP 1.338
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 1.26 SNIP 1.345
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 1.61 SNIP 1.102
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 1.476 SNIP 1.151
Original language: English
Atom probe tomography, Martensitic steels, Segregation, Synchrotron radiation, Tempering DOIs:
In Situ Investigation of the Evolution of Lattice Strain and Stresses in Austenite and Martensite During Quenching and Tempering of Steel

Energy dispersive synchrotron X-ray diffraction was applied to investigate in situ the evolution of lattice strains and stresses in austenite and martensite during quenching and tempering of a soft martensitic stainless steel. In one experiment, lattice strains in austenite and martensite were measured in situ in the direction perpendicular to the sample surface during an austenitization, quenching, and tempering cycle. In a second experiment, the \( \sin^2 \psi \) method was applied in situ during the austenite-to-martensite transformation to distinguish between macro- and phase-specific micro-stresses and to follow the evolution of these stresses during transformation. Martensite formation evokes compressive stress in austenite that is balanced by tensile stress in martensite. Tempering to 748 K (475 °C) leads to partial relaxation of these stresses. Additionally, data reveal that (elastic) lattice strain in austenite is not hydrostatic but hkl dependent, which is ascribed to plastic deformation of this phase during martensite formation and is considered responsible for anomalous behavior of the 200\( \gamma \) reflection.

General information
State: Published
Organisations: Department of Mechanical Engineering, Materials and Surface Engineering, Centre for oil and gas – DTU
Authors: Villa, M. (Intern), Niessen, F. (Intern), Somers, M. A. J. (Intern)
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Main Research Area: Technical/natural sciences

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BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): SNIP 1.28 SJR 1.093 CiteScore 2.08
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 1.91 SJR 1.206 SNIP 1.336
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.267 SNIP 1.407 CiteScore 1.78
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.659 SNIP 1.848 CiteScore 2.06
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.513 SNIP 1.656 CiteScore 1.9
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.426 SNIP 1.75 CiteScore 1.76
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.498 SNIP 1.721 CiteScore 1.78
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
Investigation on the Productivity Behaviour in Deformable Heterogeneous Fractured Reservoirs

Several hydrocarbon production wells in the North Sea reservoirs suffer from productivity reduction during primary production. Since the affected reservoirs are highly fractured, closure of natural/induced fractures around wells, due to effective stress increase is expected to be one of the main reasons for this reduction. Discrete fracture and matrix (DFM) modelling is selected in this investigation because of its ability to represent fracture behaviours more realistically. Moreover, it has become a preferential method for modelling flow in fractured formations for the past decade (Bisdom et al., 2017; Salimzadeh et al., 2018).

Mass detection, localization and estimation for wind turbine blades based on statistical pattern recognition

A method for mass change detection on wind turbine blades using natural frequencies is presented. The approach is based on two statistical tests. The first test decides if there is a significant mass change and the second test is a statistical group classification based on Linear Discriminant Analysis. The frequencies are identified by means of Operational Modal Analysis using natural excitation. Based on the assumption of Gaussianity of the frequencies, a multi-class statistical model is developed by combining finite element model sensitivities in 10 classes of change location on the blade, the smallest area being 1/5 of the span. The method is experimentally validated for a full scale wind turbine blade in a test
setup and loaded by natural wind. Mass change from natural causes was imitated with sand bags and the algorithm was observed to perform well with an experimental detection rate of 1, localization rate of 0.88 and mass estimation rate of 0.72.

**General information**

State: Published

Organisations: Department of Wind Energy, Wind Turbine Structures and Component Design, Department of Civil Engineering, Section for Structural Engineering, Centre for oil and gas – DTU, Vestas Wind Systems AS, Aarhus University

Authors: Colone, L. (Intern), Hovgaard, K. (Ekstern), Glavind, L. (Forskerdatabase), Brincker, R. (Intern)

Pages: 266-277

Publication date: 2018

Main Research Area: Technical/natural sciences

**Publication information**

Journal: Mechanical Systems and Signal Processing

Volume: 107

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BFI (2018): BFI-level 2

Web of Science (2018): Indexed yes

BFI (2017): BFI-level 1

Scopus rating (2017): SNIP 2.874 SJR 1.805 CiteScore 5.05

Web of Science (2017): Indexed yes

BFI (2016): BFI-level 1

Scopus rating (2016): CiteScore 4.84 SJR 2.03 SNIP 3.068

BFI (2015): BFI-level 1

Scopus rating (2015): SJR 1.707 SNIP 3.146 CiteScore 4.14

Web of Science (2015): Indexed yes

BFI (2014): BFI-level 1

Scopus rating (2014): SJR 1.971 SNIP 3.435 CiteScore 3.76

BFI (2013): BFI-level 1

Scopus rating (2013): SJR 1.615 SNIP 3.651 CiteScore 3.77

ISI indexed (2013): ISI indexed yes

Web of Science (2013): Indexed yes

BFI (2012): BFI-level 1

Scopus rating (2012): SJR 1.631 SNIP 3.963 CiteScore 3.26

ISI indexed (2012): ISI indexed yes

BFI (2011): BFI-level 1

Scopus rating (2011): SJR 1.61 SNIP 3.693 CiteScore 3.17

ISI indexed (2011): ISI indexed yes

Web of Science (2011): Indexed yes

BFI (2010): BFI-level 1

Scopus rating (2010): SJR 1.489 SNIP 3.087

Web of Science (2010): Indexed yes

BFI (2009): BFI-level 1

Scopus rating (2009): SJR 1.945 SNIP 3.632

BFI (2008): BFI-level 1

Scopus rating (2008): SJR 1.275 SNIP 2.684

Scopus rating (2007): SJR 1.345 SNIP 2.693

Scopus rating (2006): SJR 1.082 SNIP 2.003

Scopus rating (2005): SJR 0.94 SNIP 1.901

Scopus rating (2004): SJR 0.926 SNIP 1.45

Scopus rating (2003): SJR 0.954 SNIP 1.605

Scopus rating (2002): SJR 0.694 SNIP 1.249

Scopus rating (2001): SJR 0.895 SNIP 1.835

Scopus rating (2000): SJR 0.618 SNIP 1.225
Nonlinear multigrid solvers exploiting AMGe coarse spaces with approximation properties

This paper introduces a nonlinear multigrid solver for mixed finite element discretizations based on the Full Approximation Scheme (FAS) and element-based Algebraic Multigrid (AMGe). The AMGe coarse spaces with approximation properties used in this work enable us to overcome the difficulties in evaluating the nonlinear coarse operators and the degradation in convergence rates that characterized previous attempts to extend FAS to algebraic multilevel hierarchies on general unstructured grids. Specifically, the AMGe technique employed in this paper allows to derive stable and accurate coarse discretizations on general unstructured grids for a large class of nonlinear partial differential equations, including saddle point problems. The approximation properties of the coarse spaces ensure that our FAS approach for general unstructured meshes leads to optimal mesh-independent convergence rates similar to those achieved by geometric FAS on a nested hierarchy of refined meshes. In the numerical results, Newton’s method and Picard iterations with state-of-the-art inner linear solvers are compared to our FAS algorithm for the solution of a nonlinear saddle point problem arising from porous media flow applications. Our approach outperforms – both in terms of number of iterations and computational time – traditional methods in all the experiments.
Salt-Induced Control of the Grafting Density in Poly(ethylene glycol) Brush Layers by a Grafting-to Approach

In this work, a method to obtain control of the grafting density during the formation of polymer brush layers by the grafting-to method of thiolated poly(ethylene glycol) onto gold is presented. The grafting density of the polymer chains was adjusted by adding Na2SO4 in concentrations between 0.2 and 0.9 M to the aqueous polymer solution during the grafting process. The obtained grafting densities ranged from 0.26 to 1.60 chains nm⁻², as determined by surface plasmon resonance. The kinetics of the grafting process were studied in situ by a quartz crystal microbalance with dissipation, and a mushroom to brush conformational transition was observed when the polymer was grafted in the presence of Na2SO4. The transition from mushroom to brush was only observed for long periods of grafting, highlighting the importance of time to obtain high grafting densities. Finally, the prepared brush layer with the highest grafting density showed high resistance to the adsorption of bovine serum albumin, while layers with a lower grafting density showed only limited resistance.

General information
State: Published
Organisations: Department of Chemistry, Centre for oil and gas – DTU, Hempel AS
Authors: Ortiz, R. (Intern), Olsen, S. (Ekstern), Thormann, E. (Intern)
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Main Research Area: Technical/natural sciences

Journal: Langmuir
Volume: 34
Issue number: 15
ISSN (Print): 0743-7463
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4 SJR 1.479 SNIP 1.148
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.99 SJR 1.559 SNIP 1.178
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scenario Based Approach for Load Identification

In output only analysis the load identification has been a puzzle for several years. Different techniques have been purposed to cope with the inversion problem that lies within this field. However it has been shown, that most methods struggle to obtain robust and consistent results in cases of modal truncation and noise contaminated signals. In the light of these challenges, a scenario based method is proposed. This approach utilizes model updating along with mode shape expansion to obtain a reliable numerical model of the given structure. Then, by evaluating a series of rational load
scenarios, it is possible to obtain a reasonable input identification – both the spatial distribution and the temporal variation of the load. The method is demonstrated numerically and experimentally.

General information
State: Published
Organisations: Department of Civil Engineering, Structures and Safety, Centre for oil and gas – DTU, Aarhus University
Authors: Vigsø, M. (Ekstern), Tarpø, M. (Ekstern), Hansen, J. E. (Ekstern), Brincker, R. (Intern), Georgakis, C. T. (Intern)
Pages: 117-125
Publication date: 2018

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Volume: 2
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Seismic geomorphology and origin of diagenetic geobodies in the Upper Cretaceous Chalk of the North Sea Basin (Danish Central Graben)
Kilometre-scale geobodies of diagenetic origin have been documented for the first time in a high-resolution 3D seismic survey of the Upper Cretaceous chalks of the Danish Central Graben, North Sea Basin. Based on detailed geochemical, petrographic and petrophysical analyses it is demonstrated that the geobodies are of an open-system diagenetic origin caused by ascending basin fluids guided by faults and stratigraphic heterogeneities. Increased amounts of porosity-occluding cementation, contact cement and/or high-density/velocity minerals caused an impedance contrast that can be mapped in seismic data, and represent a hitherto unrecognized, third type of heterogeneity in the chalk deposits in addition to the well-known sedimentological and structural features. The distribution of the diagenetic geobodies is controlled by porosity/permeability contrasts of stratigraphic origin, such as hardgrounds associated with formation tops, and the feeder fault systems. One of these, the Top Campanian Unconformity at the top of the Gorm Formation, is particularly effective, and created a basin-wide barrier separating low-porosity chalk below from high-porosity chalk above (a regional porosity marker, RPM). It is in particular in this upper high-porosity unit (Tor and Ekofisk formations) that the diagenetic geobodies occur, delineated by ‘Stratigraphy Cross-cutting Reflectors’ (SCRs) of which 8 different types have been distinguished. The geobodies have been interpreted as the result of: 1) escaping pore-fluids due to top seal failure, followed by local mechanical compaction of high-porous chalks, paired with 2) ascension of basinal diagenetic fluids along fault systems that locally triggered cementation of calcite and dolomite within the chalk, causing increased contact cements and/or reducing porosity. The migration pathway of the fluids is marked by the SCRs, which are the outlines of high-density bodies of chalk nested in highly porous chalks. This study thus provides new insights into the 3D relationship between fault systems, fluid migration and diagenesis in chalks, and has important applications for basin modeling and reservoir characterization.

General information
State: Accepted/In press
Organisations: Centre for oil and gas – DTU, Technical University of Denmark, University of Copenhagen, Mærsk Oil and Gas A/S
Authors: Smit, F. W. H. (Intern), van Buchem, F. (Ekstern), Holst, J. (Ekstern), Lüthje, M. (Intern), Anderskouv, K. (Ekstern), Thibault, N. (Ekstern), Buijs, G. (Ekstern), Welch, M. (Intern), Stemmerik, L. (Ekstern)
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Surface forces between highly charged cationic polyelectrolytes adsorbed to silica: How control of pH and the adsorbed amount determines the net surface charge

Atomic force microscopy (AFM) and quartz crystal microbalance with dissipation (QCM-D) were employed to investigate the pH dependent adsorption of poly(diallyl dimethyl ammonium chloride) (polyDADMAC) to silica surfaces as well as the surface forces between these layers. It was found that polyDADMAC adopted a relatively flat conformation when adsorbed to a silica surface, and that the adsorbed amount increased with increasing pH. From the surface force measurements it is evident that the surface undergoes a charge reversal upon saturation with polyDADMAC, at the three different investigated pH values and that some degree of charge regulation of the silica surface takes place during the adsorption process. Finally, the overcharging phenomenon is discussed in terms of a geometrical mismatch due to the different average spacing between the surface charges on the silica surface and the size of the polyDADMAC monomer.
Synergy potential for oil and geothermal energy exploitation

A new solution for harvesting energy simultaneously from two different sources of energy by combining geothermal energy production and thermal enhanced heavy oil recovery is introduced. Numerical simulations are employed to evaluate the feasibility of generating energy from geothermal resources, both for thermally enhanced oil recovery from a heavy oil reservoir and for direct heating purposes. A single phase non-isothermal fluid flow modeling for geothermal doublet system and a two-phase non-isothermal fluid flow modelling for water flooding in an oil reservoir are utilised. Sensitivity and feasibility analyses of the synergy potential of thermally-enhanced oil recovery and geothermal energy production are performed. A series of simulations are carried out to examine the effects of reservoir properties on energy consumption and oil recovery for different injection rates and injection temperature. Our results show that total oil production strongly depends on the shape of heat plume which can be affected by porosity, permeability, injection temperature, well spacing and injection rate in the oil reservoir. The favourable oil recovery obtains at high amount of (a) injection rate, (b) injection temperature, (c) porosity and (d) low amount of oil reservoir permeability respectively. Furthermore, our study indicates the wellbore spacing plays an important role in oil recovery and an optimum wellbore spacing can be established. The analyses suggest that the extra amount of oil produced by utilising the geothermal energy could make the geothermal business case independent and may be a viable option to reduce the overall project cost. Furthermore, the results display that the enhance oil productions are able to reduce the required subsidy for a single doublet geothermal project up to 50%.

General information
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Authors: Ziabakhsh-Ganjii, Z. (Ekstern), Nick, H. M. (Intern), Donselaar, M. E. (Ekstern), Bruhn, D. F. (Ekstern)
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Scopus rating (2016): CiteScore 7.78 SJR 3.011 SNIP 2.61
Web of Science (2016): Indexed yes
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Scopus rating (2015): SJR 2.835 SNIP 2.593 CiteScore 6.4
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 3.158 SNIP 3.218 CiteScore 6.93
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 3.06 SNIP 3.346 CiteScore 6.59
ISI indexed (2013): ISI indexed yes
Thermoporoelastic effects during heat extraction from low-permeability reservoirs

Thermoporoelastic effects during heat extraction from low permeability geothermal reservoirs are investigated numerically, based on the model of a horizontal penny-shaped fracture intersected by an injection well and a production well. A coupled formulation for thermo-hydraulic (TH) processes is presented that implicitly accounts for the mechanical deformation of the poroelastic matrix. The TH model is coupled to a separate mechanical contact model (M) that solves for the fracture contact stresses due to thermoporoelastic compression. Fractures are modelled as surface discontinuities within a three-dimensional matrix. A robust contact model is utilised to resolve the contact tractions between opposing fracture surfaces. Results show that due to the very low thermal diffusivity of the rock matrix, the thermally-induced pore pressure partially dissipates even in the very low-permeability rocks that are found in EGS projects. Therefore, using the undrained thermal expansion coefficient for the matrix may overestimate the volumetric strain of the rock in low-permeability enhanced geothermal systems, whereas using a drained thermal expansion coefficient for the matrix may underestimate the volumetric strain of the rock. An effective thermal expansion coefficient can be computed from the drained and undrained values to improve the prediction for the partially-drained matrix.
A case hardened component of titanium
The present invention relates to a case hardened component of a titanium alloy, the component having a diffusion zone of a thickness of at least 50 μm, as calculated from the surface of the component, the diffusion zone comprising oxygen and carbon in solid solution and having a distinct phase of a carbo-oxide compound having the composition TiOxC1-x, wherein x is a number in the range of 0.01 to 0.99, which diffusion zone has a microhardness of at least 800 HV0.025 and which carbo-oxide compound has a microhardness of at least 1200 HV0.025. In another aspect the invention relates to a method of producing the case hardened component. In a further aspect the invention relates to a method of oxidising a component of a Group IV metal.
Additively manufactured metallic porous biomaterials based on minimal surfaces: A unique combination of topological, mechanical, and mass transport properties

Porous biomaterials that simultaneously mimic the topological, mechanical, and mass transport properties of bone are in great demand but are rarely found in the literature. In this study, we rationally designed and additively manufactured (AM) porous metallic biomaterials based on four different types of triply periodic minimal surfaces (TPMS) that mimic the properties of bone to an unprecedented level of multi-physics detail. Sixteen different types of porous biomaterials were rationally designed and fabricated using selective laser melting (SLM) from a titanium alloy (Ti-6Al-4V). The topology, quasi-static mechanical properties, fatigue resistance, and permeability of the developed biomaterials were then characterized. In terms of topology, the biomaterials resembled the morphological properties of trabecular bone including mean surface curvatures close to zero. The biomaterials showed a favorable but rare combination of relatively low elastic properties in the range of those observed for trabecular bone and high yield strengths exceeding those reported for cortical bone. This combination allows for simultaneously avoiding stress shielding, while providing ample mechanical support for bone tissue regeneration and osseointegration. Furthermore, as opposed to other AM porous biomaterials developed to date for which the fatigue endurance limit has been found to be of their yield (or plateau) stress, some of the biomaterials developed in the current study show extremely high fatigue resistance with endurance limits up to 60% of their yield stress. It was also found that the permeability values measured for the developed biomaterials were in the range of values reported for trabecular bone. In summary, the developed porous metallic biomaterials based on TPMS mimic the topological, mechanical, and physical properties of trabecular bone to a great degree. These properties make them potential candidates to be applied as parts of orthopedic implants and osseointegration. The fatigue resistance of the developed biomaterials is also exceptionally high, while their permeability is in the range of values reported for bone. (C) 2017 Acta Materialia Inc. Published by Elsevier Ltd. All rights reserved.
An evaluation of interferences in heat production from low enthalpy geothermal doublets systems

Required distance between doublet systems in low enthalpy geothermal heat exploitation is often not fully elucidated. The required distance aims to prevent negative interference influencing the utilisation efficiency of doublet systems. Currently production licence areas are often issued based on the expected extent of the reinjected cold water plume on the moment of thermal breakthrough. The production temperature, however, may not immediately drop to non-economic values after this moment. Consequently, heat production could continue increasing the extent of the cold water plume. Furthermore, the area influenced by pressure because of injection and production spreads beyond the cold water plume extent, influencing not only the productivity of adjacent doublet systems but also the shape of cold water plumes. This affects doublet lifetime, especially if adjacent doublets have different production rates. In this modelling based study a multi parameter analysis is carried out to derive dimensionless relations between basic doublet design parameters and required doublet distance. These parameters include the spacing between injector and producer of the same doublet, different production rates, aquifer thickness and minimal required production temperature. The results of this study can be used to minimize negative interference or optimise positive interference aiming at improving geothermal doublet deployment efficiency. (C) 2017 The Authors. Published by Elsevier Ltd.
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Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.942 SNIP 1.153
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.703 SNIP 1.105
Scopus rating (2003): SJR 1.024 SNIP 1.45
Scopus rating (2002): SJR 0.806 SNIP 1.257
Scopus rating (2001): SJR 1.079 SNIP 1.089
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.698 SNIP 0.962
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An integrated workflow for stress and flow modelling using outcrop-derived discrete fracture networks

Fluid flow in naturally fractured reservoirs is often controlled by subseismic-scale fracture networks. Although the fracture network can be partly sampled in the direct vicinity of wells, the inter-well scale network is poorly constrained in fractured reservoir models. Outcrop analogues can provide data for populating domains of the reservoir model where no direct measurements are available. However, extracting relevant statistics from large outcrops representative of inter-well scale fracture networks remains challenging. Recent advances in outcrop imaging provide high-resolution datasets that can cover areas of several hundred by several hundred meters, i.e. the domain between adjacent wells, but even then, data from the high-resolution models is often upscaled to reservoir flow grids, resulting in loss of accuracy. We present a workflow that uses photorealistic georeferenced outcrop models to construct geomechanical and fluid flow models containing thousands of discrete fractures covering sufficiently large areas, that does not require upscaling to model permeability. This workflow seamlessly integrates geomechanical Finite Element models with flow models that take into account stress-sensitive fracture permeability and matrix flow to determine the full permeability tensor. The applicability of this workflow is illustrated using an outcropping carbonate pavement in the Potiguar basin in Brazil, from which 1082 fractures are digitised. The permeability tensor for a range of matrix permeabilities shows that conventional upscaling to effective grid properties leads to potential underestimation of the true permeability and the orientation of principal permeabilities. The presented workflow yields the full permeability tensor model of discrete fracture networks with stress-induced apertures, instead of relying on effective properties as most conventional flow models do.

General information
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Organisations: Centre for oil and gas – DTU, Delft University of Technology
Authors: Bisdom, K. (Ekstern), Nick, H. (Intern), Bertotti, G. (Ekstern)
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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): SNIP 1.583 SJR 1.35 CiteScore 2.96
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 1.084 SNIP 1.841 CiteScore 2.93
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.165 SNIP 1.714 CiteScore 2.67
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.073 SNIP 1.807 CiteScore 2.52
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.794 SNIP 1.609 CiteScore 2.06
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.868 SNIP 1.816 CiteScore 2.1
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.871 SNIP 1.694 CiteScore 2.02
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.939 SNIP 1.656
Applying LCA in decision making- the need and the future perspective

General information
State: Published
Organisations: Department of Management Engineering, Quantitative Sustainability Assessment, Department of Civil Engineering, Centre for oil and gas – DTU, Transport DTU, Transport Modelling, Department of Applied Mathematics and Computer Science, Statistics and Data Analysis, Department of Environmental Engineering, Urban Water Systems, National Food Institute, Research Group for Genomic Epidemiology, Section for Structural Engineering
Authors: Dong, Y. (Intern), Miraglia, S. (Intern), Manzo, S. (Intern), Georgiadis, S. (Intern), Sørup, H. J. D. (Intern), Boriani, E. (Intern), Hald, T. (Intern), Thöns, S. (Intern), Hauschild, M. Z. (Intern)
Number of pages: 1
Publication date: 2017
Main Research Area: Technical/natural sciences
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Activities:
Applying LCA in decision making- the need and the future perspective
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2017

Calibration of the NDHA N2O model via respirometric assays

General information
State: Published
Organisations: Department of Environmental Engineering, Water Technologies, Department of Chemical and Biochemical Engineering, PROSYS - Process and Systems Engineering Centre, Centre for oil and gas – DTU, Technical University of Denmark
Authors: Domingo-Felez, C. (Intern), Calderó-Pascual, M. (Ekstern), Sin, G. (Intern), Plósz, B. G. (Intern), Smets, B. F. (Intern)
Number of pages: 4
Publication date: 2017
Complementary Methods for the Characterization of Corrosion Products on a Plant-Exposed Superheater Tube

In this work, complex corrosion products on a superheater tube exposed to biomass firing were characterized by the complementary use of energy-dispersive synchrotron diffraction, electron microscopy, and energy-dispersive X-ray spectroscopy. Non-destructive synchrotron diffraction in transmission geometry measuring with a small gauge volume from the sample surface through the corrosion product allowed depth-resolved phase identification and revealed the presence of (Fe,Cr)2O3 and FeCr2O4. This was supplemented by microstructural and elemental analysis correlating the additional presence of a Ni-rich austenite phase to selective removal of Fe and Cr from the alloy, via a KCl-induced corrosion mechanism. Compositional variations were related to diffraction results and revealed a qualitative influence of the spinel cation concentration on the observed diffraction lines.
best parameter set. Therefore, in this work two parameter sets have been chosen for the sPC-SAFT EOS for a fair comparison. The comparisons are made for pure fluid properties, vapor liquid-equilibria, and liquid liquid equilibria of binary and ternary mixtures as well as vapor liquid liquid equilibria of quaternary mixtures. The results show, from an overall point of view, that these two models have equally good performance, and the two parameter sets with the sPC-SAFT EOS are also comparable, especially for the vapor liquid equilibria systems. Moreover, the modeling results suggest that some data are less reliable than others, which indicates the need for more measurements to further validate the models, especially for multicomponent systems.

General information
State: Published
Organisations: Center for Energy Resources Engineering, Centre for oil and gas – DTU, Department of Chemical and Biochemical Engineering, CERE – Center for Energy Resources Engineering, KT Consortium, Technical University of Denmark
Authors: Liang, X. (Intern), Aloupis, G. (Ekstern), Kontogeorgis, G. M. (Intern)
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Scopus rating (2017): CiteScore 2.33 SJR 0.925 SNIP 1.116
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.29 SJR 0.866 SNIP 1.103
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.857 SNIP 0.954 CiteScore 1.96
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.015 SNIP 1.196 CiteScore 2.22
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.131 SNIP 1.196 CiteScore 2.17
ISI indexed (2013): ISI indexed yes
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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.139 SNIP 1.102 CiteScore 2.01
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.858 SNIP 0.977 CiteScore 1.8
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.055 SNIP 1.298
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.308 SNIP 1.031
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.505 SNIP 1.19
The production of single-cell protein (SCP) in a U-loop reactor by a methanotroph is a cost efficient sustainable alternative to protein from fish meal obtained by over-fishing the oceans. SCP serves as animal feed. In this paper, we present a mathematical model that describes the dynamics of SCP production in a U-loop reactor. We use this model to compute an optimal start-up trajectory by solution of an economic optimizing optimal control problem. The optimal start-up trajectory is an unstable attractor. The practical implementation of this optimal start-up trajectory can be conducted by a proportional controller for the substrate concentration in the top tank of the U-loop reactor.

Economic Optimizing Control for Single-Cell Protein Production in a U-Loop Reactor

The production of single-cell protein (SCP) in a U-loop reactor by a methanotroph is a cost efficient sustainable alternative to protein from fish meal obtained by over-fishing the oceans. SCP serves as animal feed. In this paper, we present a mathematical model that describes the dynamics of SCP production in a U-loop reactor. We use this model to compute an optimal start-up trajectory by solution of an economic optimizing optimal control problem. The optimal start-up trajectory is an unstable attractor. The practical implementation of this optimal start-up trajectory can be conducted by a proportional controller for the substrate concentration in the top tank of the U-loop reactor.
Effect of Foam on Liquid Phase Mobility in Porous Media

We investigate the validity of the assumption that foam in porous media reduces the mobility of gas phase only and does not impact the liquid-phase mobility. The foam is generated by simultaneous injection of nitrogen gas and a surfactant solution into sandstone cores and its strength is varied by changing surfactant type and concentration. We find, indeed, that the effect of foam on liquid-phase mobility is not pronounced and can be ignored. Our new experimental results and analyses resolve apparent discrepancies in the literature. Previously, some researchers erroneously applied relative permeability relationships measured at small to moderate capillary numbers to foam floods at large capillary number. Our results indicate that the water relative permeability in the absence of surfactant should be measured with the capillary pressure ranging up to values reached during the foam floods. This requires conducting a steady-state gas/water core flood with capillary numbers similar to that of foam floods or measuring the water relative-permeability curve using a centrifuge.

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Authors: Eftekhari, A. A. (Intern), Farajzadeh, R. (Ekstern)
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Scopus rating (2017): CiteScore 4.36 SJR 1.533 SNIP 1.245
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 4.63 SJR 1.692 SNIP 1.354
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.034 SNIP 1.597 CiteScore 5.3
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.163 SNIP 1.554 CiteScore 4.75
Web of Science (2014): Indexed yes
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Scopus rating (2013): SJR 1.998 SNIP 1.57 CiteScore 4.06
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.531 SNIP 0.962 CiteScore 2.44
ISI indexed (2012): ISI indexed yes
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Untitled.pdf
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Publication: Research - peer-review › Journal article – Annual report year: 2017
Effect of Poroelasticity on Hydraulic Fracture Interactions
This study investigates, by performing finite element-based simulations, the influence of fluid leak-off and poroelasticity on growth of multiple hydraulic fractures that initiate from a single horizontal well. In this research, poroelastic deformation of the matrix is coupled with fluid flow in the fractures, and fluid flow in the rock matrix, in three dimensions. Effects of the fluid leak-off and poroelasticity on the propagation of the neighboring fractures are studied by varying the matrix permeability, and the Biot coefficient. Simulation results show that the stress induced by the opening of the fractures, and the stress induced by the fluid leak-off, each have the effect of locally altering the magnitudes and orientations of the principal stresses, hence altering the propagation direction of the fractures. The stress induced by the opening of the fractures tends to propagate both of the fractures away from each other in a curved trajectory, whereas the effects of fluid leak-off and poroelasticity (i.e., a higher Biot coefficient) tend to straighten the curved trajectory.

General information
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Organisations: Centre for oil and gas – DTU, Cosmo Energy Exploration and Production, Imperial College London
Authors: Usui, T. (Ekstern), Salimzadeh, S. (Intern), Paluszny, A. (Ekstern), Zimmerman, R. W. (Ekstern)
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Electrical Double-Layer and Ion Bridging Forces between Symmetric and Asymmetric Charged Surfaces in the Presence of Mono- and Divalent Ions
An atomic force microscope, employing the colloidal probe technique, was used to study the interactions between six different combinations of silane-functionalized silica surfaces in NaCl and CaCl₂ solutions. The surfaces consisted of monolayers of the apolar trimethoxy(octyl)silane, the positively charged (3-aminopropyl)trimethoxysilane, and the negatively charged (3-mercaptopropyl)trimethoxysilane. The interactions between the three symmetric systems, as well as between the three asymmetric combinations of surfaces, were measured and compared to calculated electrical double-layer forces. The results demonstrated that the long-range interactions between the surfaces in all cases were dominated by double-layer forces, while short-range interactions, including adhesion, were dominated by ion bridging forces in the cases where both interaction surfaces favored adsorption of calcium ions. The study thus also demonstrates how surface force studies in mono- and divalent salt solutions can be used as an analytical tool for probing specific functional groups on heterogeneous surfaces.

General information
State: Published
Organisations: Department of Chemistry, Centre for oil and gas – DTU, Center for Energy Resources Engineering, Department of Chemical and Biochemical Engineering, CERE – Center for Energy Resources Engineering
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Volume: 33
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BFI (2018): BFI-level 1
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BFI (2017): BFI-level 2
Energy and exergy analysis of alternating injection of oxygen and steam in the low emission underground gasification of deep thin coal

Recent studies have shown that by coupling the underground coal gasification (UCG) with the carbon capture and storage (CCS), the coal energy can be economically extracted with a low carbon footprint. To investigate the effect of UCG and CCS process parameters on the feasibility of the UCG-CCS process, we utilize a validated mathematical model, previously published by the same authors, that can predict the composition of the UCG product, temperature profile, and coal conversion rate for alternating injection of air and steam for unmineable deep thin coal layers. We use the results of the model to conduct an energy and exergy analysis of the UCG process. We study the effect of various process parameters on the efficiency of the UCG process, the zero-emission recovery factor of coal, and the total CO₂ emission of the process. Moreover, we compare the alternating injection of air/steam with the injection of an air and steam mixture. Exergy analysis shows that the alternating injection of air/steam describes a practical process for UCG at low pressure. However, injecting a mixture of steam and oxygen results in a practical recovery factor of coal higher than the alternating injection process. Additionally, we show that the zero-emission conversion of unmineable deep thin coal resources in a coupled UCG-CCS process, that is not practical with the current state of technology, can be realized by increasing the energy efficiency of the carbon dioxide capture process.

General information
State: Published
Organisations: Centre for oil and gas – DTU, Delft University of Technology, Central Mining Institute
Authors: Eftekhari, A. A. (Intern), Wolf, K. H. (Ekstern), Rogut, J. (Ekstern), Bruining, H. (Ekstern)
Number of pages: 10
Pages: 62-71
Publication date: 2017
Main Research Area: Technical/natural sciences

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Journal: Applied Energy
Volume: 208
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Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 8.44 SJR 3.162 SNIP 2.765
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 7.78 SJR 3.011 SNIP 2.61
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.835 SNIP 2.593 CiteScore 6.4
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 3.158 SNIP 3.218 CiteScore 6.93
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 3.06 SNIP 3.346 CiteScore 6.59
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.778 SNIP 3.076 CiteScore 5.69
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 2.416 SNIP 2.827 CiteScore 5.5
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Experimental investigation of interfacial crack arrest in sandwich beams subjected to fatigue loading using a novel crack arresting device

A recently proposed face-sheet–core interface crack arresting device is implemented in sandwich beams and tested using the Sandwich Tear Test configuration. Fatigue loading conditions are applied to propagate the crack and determine the effect of the crack stopper on the fatigue growth rate and arrest of the crack. Digital image correlation is used through the duration of the fatigue experiment to track the strain evolution as the crack tip advances. The measured strains are related to crack tip propagation, arrest, and re-initiation of the crack. A finite element model is used to calculate the energy release rate, mode mixity and to simulate crack propagation and arrest of the crack. Finally, the effectiveness of the crack arresting device is demonstrated on composite sandwich beams subjected to fatigue loading conditions.

General information
State: Published
Organisations: Centre for oil and gas – DTU, Department of Mechanical Engineering, Solid Mechanics, Aalborg University
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Number of pages: 21
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Publication information
Journal: Journal of Sandwich Structures and Materials
Volume: 0
ISSN (Print): 1099-6362
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.74 SJR 0.998 SNIP 0.913
Experimental study of strain prediction on wave induced structures using modal decomposition and quasi static Ritz vectors

Offshore structures are continuously subjected to dynamic loading from wind and waves which makes fatigue an important parameter for the structures expected lifetime. Monitoring the vibrations of the structure using real time operating data enables an assessment of the general health state of the structure. This paper proposes a method for an accurate full-field prediction of the strain history. Experimental mode shapes are found by the use of operational modal analysis and expanded to strain modes using a well correlated finite element model. The measured response from the structure is divided into two parts using complementary filters: Low frequency response caused by the quasi-static effect of the waves acting on the structure, and the high frequency response given by the modal properties of the structure. The high frequency response is then decomposed into modal coordinates using the experimental mode shapes. Strain histories are predicted by multiplying the modal coordinates with the expanded strain mode shapes. The low frequency response is decomposed using Ritz-vectors corresponding to the shapes that the structure vibrates with due to the wave loading.
Strain Ritz-vectors are then extracted from the finite element model by applying a load corresponding to a representative wave and the strain history for the low frequency response is found by multiplying the decomposed signal with the strain Ritz-vectors. Finally the combined strain history is found by adding the strain histories from the low and high frequency responses. To validate the theory tests were performed on a scaled model of an offshore structure where the strain history was predicted using only the response from the accelerometers.
Finite element simulations of interactions between multiple hydraulic fractures in a poroelastic rock

A fully coupled three-dimensional finite-element model for hydraulic fractures in permeable rocks is presented, and used to investigate the ranges of applicability of the classical analytical solutions that are known to be valid in limiting cases. This model simultaneously accounts for fluid flow within the fracture and rock matrix, poroelastic deformation, propagation of the fractures, and fluid leakage into the rock formation. The model is validated against available asymptotic analytical solutions for penny-shaped fractures, in the viscosity-dominated, toughness-dominated, storage-dominated, and leakoff-dominated regimes. However, for intermediate regimes, these analytical solutions cannot be used to predict the key hydraulic fracturing variables, i.e. injection pressure, fracture aperture, and length. For leakoff-dominated cases in permeable rocks, the asymptotic solutions fail to accurately predict the lower-bound for fracture radius and apertures, and the upper-bound for fracture pressure. This is due to the poroelastic effects in the dilated rock matrix, as well as due to the multi-dimensional flow within matrix, which in many simulation codes is idealised as being one-dimensional, normal to the fracture plane.

General information
State: Published
Organisations: Centre for oil and gas – DTU, Imperial College London
Authors: Salimzadeh, S. (Intern), Usui, T. (Ekstern), Paluszny, A. (Ekstern), Zimmerman, R. W. (Ekstern)
Pages: 9-20
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Volume: 99
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BFI (2008): BFI-level 1
Scopus rating (2002): SJR 0.121
Scopus rating (2001): SJR 0.121
Scopus rating (2000): SJR 0.373
Scopus rating (1999): SJR 0.303 SNIP 2.893
Original language: English
Multiple hydraulic fractures, Sequential fracturing, Simultaneous fracturing, Linear elastic fracture mechanics
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Publication: Research - peer-review › Journal article – Annual report year: 2017

Geomechanics and geology: introduction

General information
State: Published
Organisations: Centre for oil and gas – DTU, Radioactive Waste Management Ltd., University of Aberdeen, Deep Exploration Technologies Co-operative Research Centre
Authors: Turner, J. P. (Ekstern), Healy, D. (Ekstern), Hillis, R. R. (Ekstern), Welch, M. J. (Intern)
Number of pages: 5
Including product features in process redesign

This article suggests a visual modelling method for integrating models of product features with business process models for redesigning the business processes involving specifications of customer-tailored products and services. The current methods for redesigning these types of business processes do not take into account how the product features are applied throughout the process, which makes it difficult to obtain a comprehensive understanding of the activities in the processes and to generate significant improvements. The suggested approach models the product family using the so-called product variant master and the business process modelling notation for modelling the process flow. The product model is combined with the process map by identifying features used in each step of the process flow. Additionally, based on the information absorbed from the integrated model, the value stream mapping modelling technique is applied to the specification process to evaluate its performance in quantifiable terms. The proposed modelling approach was investigated through three case studies. Experiences from the case studies were that the suggested modelling techniques gave additional insight into the specification processes and formed a good basis for process improvement. Furthermore, the case studies indicated that the suggested modelling techniques were applicable and easy to use.
Kinetics analysis of two-stage austenitization in supermartensitic stainless steel

The martensite-to-austenite transformation in X4CrNiMo16-5-1 supermartensitic stainless steel was followed in-situ during isochronal heating at 2, 6 and 18 K min⁻¹ applying energy-dispersive synchrotron X-ray diffraction at the BESSY II facility. Austenitization occurred in two stages, separated by a temperature region in which the transformation was strongly decelerated. The region of limited transformation was more concise and occurred at higher austenite phase fractions and temperatures for higher heating rates. The two-step kinetics was reproduced by kinetics modeling in DICTRA. The model indicates that the austenitization kinetics is governed by Ni-diffusion and that slow transformation kinetics separating the two stages is caused by soft impingement in the martensite phase. Increasing the lath width in the kinetics model had a similar effect on the austenitization kinetics as increasing the heating-rate.

General information
State: Published
Organisations: Centre for oil and gas – DTU, Department of Mechanical Engineering, Materials and Surface Engineering
Authors: Nießen, F. (Intern), Villa, M. (Intern), Hald, J. (Intern), Somers, M. A. J. (Intern)
Number of pages: 8
Pages: 8-15
Publication date: 2017
Main Research Area: Technical/natural sciences
Supermartensitic stainless steels, Phase transformation kinetics, Interface diffusion, Synchrotron radiation, Kinetics modeling, Reversed austenite

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Kinetics modeling of delta-ferrite formation and retainment during casting of supermartensitic stainless steel

The kinetics model for multi-component diffusion DICTRA was applied to analyze the formation and retainment of δ-ferrite during solidification and cooling of GX4-CrNiMo-16-5-1 cast supermartensitic stainless steel. The obtained results were compared with results from the Schaeffler diagram, equilibrium calculations and the Scheil model in Thermo-Calc, and validated by using microscopy and energy dispersive X-ray spectroscopy for chemical analysis on a cast ingot. The kinetics model showed that micro-segregation from solidification homogenizes within 2–3 s (70 °C) of cooling, and that retained δ-ferrite originates from the incomplete transformation to austenite. The kinetics model predicted the measured amount of δ-ferrite and the partitioning of Cr and Ni reasonably well. Further, it showed that slower cooling for the investigated alloy leads to less retained δ-ferrite, which is in excellent agreement with experimental results.

General information
State: Published
Organisations: Centre for oil and gas – DTU, Department of Mechanical Engineering, Manufacturing Engineering, Materials and Surface Engineering
Authors: Nießen, F. (Intern), Tiedje, N. S. (Intern), Hald, J. (Intern)
Pages: 138-145
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Materials & Design
Volume: 118
ISSN (Print): 0264-1275
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): SJR 1.82 SNIP 2.424 CiteScore 5.16
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 4.9 SJR 1.76 SNIP 2.547
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.844 SNIP 2.623 CiteScore 4.51
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.364 SNIP 3.403 CiteScore 4.36
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.024 SNIP 3.215 CiteScore 3.8
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.963 SNIP 3.171 CiteScore 3.31
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.387 SNIP 2.501 CiteScore 2.63
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.058 SNIP 1.845
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.931 SNIP 1.808
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.961 SNIP 1.355
Scopus rating (2007): SJR 0.83 SNIP 1.674
Scopus rating (2006): SJR 0.66 SNIP 1.416
Modal participation in multiple input Ibrahim time domain identification

General information
State: Accepted/In press
Organisations: Department of Civil Engineering, Section for Structural Engineering, Centre for oil and gas – DTU, Aarhus University, University College Dublin, Semnan University
Authors: Brincker, R. (Intern), Olsen, P. (Ekstern), Amador, S. (Intern), Juul, M. (Ekstern), Malekjafarian, A. (Ekstern), Ashory, M. (Ekstern)
Publication date: 2017
Main Research Area: Technical/natural sciences

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Journal: Mathematics and Mechanics of Solids
ISSN (Print): 1081-2865
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
Scopus rating (2017): SNIP 0.989 SJR 0.768 CiteScore 1.88
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.6 SNIP 1.079 SJR 1.165
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.03 SNIP 0.978 SJR 0.632
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 0.87 SNIP 0.823 SJR 0.654
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 0.81 SNIP 0.838 SJR 0.547
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 0.99 SNIP 1.178 SJR 0.801
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 1 SNIP 1.303 SJR 0.836
BFI (2010): BFI-level 1
Scopus rating (2010): SNIP 1.017 SJR 0.76
BFI (2009): BFI-level 1
Scopus rating (2009): SNIP 0.82 SJR 0.62
BFI (2008): BFI-level 1
Scopus rating (2008): SNIP 0.625 SJR 0.487
Scopus rating (2007): SNIP 0.867 SJR 0.697
Scopus rating (2006): SNIP 0.7 SJR 0.61
Scopus rating (2005): SNIP 1.285 SJR 1.544
Scopus rating (2004): SNIP 0.766 SJR 0.64
Oma modal indication by sensitivity to added artificial noise

This paper presents a modal indicator for use in OMA identification techniques relying on the correlation function for extraction of parameters. We propose to add small amounts of artificial white Gaussian noise to the correlation function and measuring the sensitivity of the identified modes to this noise. The idea is to identify system parameters many times, each time adding a tiny amount of uncorrelated white Gaussian noise to the correlation function. Since the noise modes are more affected by the adding of tiny amounts of additional noise, than the physical modes, the variance of the estimated parameters gives an effective modal indicator.

On minimizing the influence of the noise tail of correlation functions in operational modal analysis

In operational modal analysis (OMA) correlation functions are used by all classical time-domain modal identification techniques that uses the impulse response function (free decays) as primary data. However, the main difference between the impulse response and the correlation functions estimated from the operational responses is that the latter presents a higher noise level. This is due to statistical errors in the estimation of the correlation function and it causes random noise in the end of the function and this is called the noise tail. This noise might have significant influence on the identification results (random errors) when the noise tail is included in the identification. On the other hand, if the correlation function is truncated too much, then important information is lost. In order to minimize this error, a suitable truncation based on manual inspection of the correlation function is normally used. However, in automated OMA, an automated procedure is needed for the truncation. Based on known theoretical solutions from the literature, a model is proposed in this paper to automatically truncate the correlation function at the point where it starts to get dominated by the noise tail. The accuracy of the proposed truncation procedure is studied using a three degree of freedom simulation case.
On the connectivity anisotropy in fluvial Hot Sedimentary Aquifers and its influence on geothermal doublet performance

This study finds that the geothermal doublet layout with respect to the paleo flow direction in fluvial sedimentary reservoirs could significantly affect pump energy losses. These losses can be reduced by up to 10% if a doublet well pair is oriented parallel to the paleo flow trend compared to perpendicular. The chance that flow paths are formed perpendicular to this trend strongly depends on the net sandstone volume in the reservoir. Detailed fluvial facies architecture realisations which are used in this study, are generated with a process-based approach utilizing geological data from the Lower Cretaceous Nieuwerkerk Formation in the West Netherlands Basin. Finally, this study emphasizes the importance of detailed facies architecture modelling for the assessment of both risks and production strategies in Hot Sedimentary Aquifers.

General information
State: Published
Organisations: Centre for oil and gas – DTU, Delft University of Technology, University of Leuven
Authors: Willems, C. J. (Ekstern), Nick, H. (Intern), Donselaar, M. E. (Ekstern), Weltje, G. J. (Ekstern), Bruhn, D. F. (Ekstern)
Number of pages: 12
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Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Geothermics
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ISSN (Print): 0375-6505
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  Web of Science (2018): Indexed yes
  BFI (2017): BFI-level 1
  Scopus rating (2017): SNIP 1.908 SJR 1.263 CiteScore 3.14
  Web of Science (2017): Indexed yes
  BFI (2016): BFI-level 1
  Scopus rating (2016): CiteScore 2.67 SJR 1.01 SNIP 1.55
  Web of Science (2016): Indexed yes
  BFI (2015): BFI-level 1
  Scopus rating (2015): SJR 1.328 SNIP 2.036 CiteScore 2.99
  Web of Science (2015): Indexed yes
Operational modal analysis based prediction of actual stress in an offshore structural model

In this paper the accuracy of predicting stresses directly from the operational responses is investigated. The basic approach to the stress prediction is to perform an operational modal analysis (OMA) and then applying a modal filtering to the operating response, so that the modal coordinates of all significant modes are known. Next, the experimental mode shapes are expanded using a finite element (FE) model together with the local correspondence principle to estimate the displacements in all degrees of freedom of the FE model, and strain is predicted using the strain mode shapes. The accuracy of the approach is assessed by comparing the predicted and measured strains.

General information

State: Published
Organisations: Centre for oil and gas – DTU, Department of Civil Engineering, Section for Structural Engineering, Aarhus University, Rambøll Oil and Gas
Authors: Glindtvad Tarpø, M. (Intern), Silva Nabuco, B. (Intern), Skafte, A. (Ekstern), Kristoffersen, J. (Ekstern), Vestermark, J. (Ekstern), Diord Rescinho Amador, S. (Intern), Brincker, R. (Intern)
Number of pages: 6
Pages: 2262-2267
Publication date: 2017
Conference: X International Conference on Structural Dynamics, Rome, Italy, 10/09/2017 - 10/09/2017
Main Research Area: Technical/natural sciences
Pore-Scale Investigation of Crude Oil/CO₂ Compositional Effects on Oil Recovery by Carbonated Water Injection

Through coreflood and micromodel studies, it has been shown that carbonated water injection (CWI) can improve oil recovery compared to conventional waterflood. However, in most early studies, either a refined oil or dead crude oil had been used, which is not representative of a real oil reservoir where the oil has significant dissolved gases. In such studies, oil swelling and oil viscosity reduction had been introduced as the main mechanisms of additional oil recovery by CWI. However, in our direct flow visualization (micro model) studies reported here, we have used live crude oil, and we have observed the formation and growth of a new gaseous phase inside the oil when it comes in contact with carbonated water (CW). The aim of this work is to visually study the effect of this phenomenon on oil recovery by CWI at pore scale. In this paper, we present the results of two high-pressure high-temperature direct flow visualization (micromodel) experiments which have been performed using a live crude oil sample. These include a tertiary (post-waterflood) and a secondary (pre-waterflood) CWI experiment performed at 2500 psia and 100 degrees F. The results of our secondary and tertiary CWI showed that CWI can improve the oil displacement and recovery compared to conventional waterflood. Although both secondary and tertiary CWI improved oil recovery significantly, the performance of CWI was better when it was injected instead of conventional waterflood (secondary) rather than after conventional waterflood (tertiary). On the basis of our study, the predominant mechanism that led to this additional oil recovery was the formation and growth of a new gaseous phase within the oil. Formation of the new phase improved the oil recovery through (i) reconnection of the trapped oil and oil displacement, (ii) creating a favorable three phase flow region with less residual oil saturation, and (iii) restricting the flow path of OAT and diverting it toward unswept areas of the porous medium. Formation of the new phase happened faster and stronger when CW was injected as secondary, and its final saturation, for a fixed period of CWI, was higher than its final saturation in tertiary CWI. We also show that the nucleation and growth of the new gaseous phase is directly proportional to the amount of hydrocarbon gas dissolved in the oil which is a function of oil properties and saturation pressure and temperature.

General information
State: Published
Organisations: Centre for oil and gas – DTU, Heriot-Watt University
Authors: Seyyedi, M. (Intern), Sohrabi, M. (Ekstern)
Number of pages: 11
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Main Research Area: Technical/natural sciences
Quantification of oil recovery efficiency, CO2 storage potential, and fluid-rock interactions by CWI in heterogeneous sandstone oil reservoirs

Significant interest exists in improving recovery from oil reservoirs while addressing concerns about increasing CO2 concentrations in the atmosphere. The combination of Enhanced Oil Recovery (EOR) and safe geologic storage of CO2 in oil reservoirs is appealing and can be achieved by carbonated (CO2-enriched) water injection (CWI). So far, through several flooding experiments, the potential of carbonated water injection as an EOR scenario has been investigated. While several coreflood experiments on homogeneous cores have been performed, there is no information on the effectiveness of CWI for oil recovery and CO2 storage potential on heterogeneous cores. Since not all the oil reservoirs are homogenous, understanding the potential of CWI as an integrated EOR and CO2 storage scenario in heterogeneous oil reservoirs is essential.

General information
State: Published
Organisations: Centre for oil and gas – DTU, Heriot-Watt University
Authors: Seyyedi, M. (Intern), Sohrabi, M. (Ekstern), Sisson, A. (Ekstern), Ireland, S. (Ekstern)
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Main Research Area: Technical/natural sciences

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Journal: Journal of Molecular Liquids
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BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): SJR 0.849 SNIP 1.238 CiteScore 4.26
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.47 SJR 0.717 SNIP 1.222
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.646 SNIP 0.994 CiteScore 2.61
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.641 SNIP 1.118 CiteScore 2.34
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.608 SNIP 1.063 CiteScore 2.07
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.679 SNIP 1.04 CiteScore 1.62
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.615 SNIP 1.087 CiteScore 1.64
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Reliability analysis of offshore structures using OMA based fatigue stresses

Today, many offshore structures in the North Sea already reached their predicted lifetime. Since it is still required a huge demand of oil, it results in an important need to keep those structures in operation. The great attention concerning the lifetime of offshore platforms has triggered a need for monitoring these structures in order to gain information about their actual state and hence reduce the uncertainty and allow for more optimal decision planning regarding maintenance, repair and future inspection actions.

Throughout the lifetime, the performance of the structure can be evaluated by analyzing the deterioration process of the structure. In the offshore environment, one of the most common deterioration mechanisms is the fatigue of structural steel induced by wave loading. The deterioration formulation of a structural system subjected to fatigue is nowadays well known. However, many uncertainties may affect the accuracy of the performance evaluation. It can be mentioned mainly the uncertainties related to the materials, the uncertainty on Miner's rule and the uncertainty on the SN curve but most importantly is the uncertainty on the stress ranges induced by the wave loading.

In this paper, the main focus is on the uncertainty observed on the different stresses used to predict the damage. This uncertainty can be reduced by Modal Based Fatigue Monitoring which is a technique based on continuously measuring of the accelerations in few points of the structure with the use of accelerometers known as reliable for long time measurements. An Operational Modal Analysis (OMA) is performed and then a modal filtering of the operating response is considered, so that the modal coordinates of all significant modes are known. Next, the experimental mode shapes are expanded using a Finite Element (FE) model together with the Local Correspondence (LC) principle and the displacements can be estimated in all degrees of freedom of the FE model, allowing the stresses and strains to be obtained from the element equations. It is important to emphasize that even though the accelerations are measured in only a few points of the structure, the stress history can be calculated in any arbitrary point of the structure.

The accuracy of the estimated actual stress is analyzed by experimental tests on a scale model where the obtained stresses are compared to strain gauges measurements. After evaluating the fatigue stresses directly from the operational response of the structure, a reliability analysis is performed in order to estimate the reliability of using Modal Based Fatigue Monitoring for long term fatigue studies.

General information
State: Published
Organisations: Centre for oil and gas – DTU, Department of Civil Engineering, Section for Structural Engineering
Authors: Silva Nabuco, B. (Intern), Aissani, A. (Intern), Glindtvad Tarpe, M. (Intern), Brincker, R. (Intern)
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Article number: OMAE2017-61730
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BFI conference series: International Conference on Ocean, Offshore and Arctic Engineering (5010067)
Resilience of systems by value of information and SHM

Critical infrastructure systems such as energy provision and distribution systems, transport systems and the built environment in general are subject to and sensitive to deterioration processes. Structural Health Monitoring (SHM) strategies have been increasingly employed as means to detect deterioration, facilitate timely and efficient interventions and thereby to enhance resilience of critical infrastructure. However, in specific situations, it is generally not obvious if and to what degree different SHM strategies are efficient and sufficient for enhancing the resilience of critical infrastructure systems. In response to this challenge, the present contribution puts forwards a novel approach, taking basis in the concept of value of information analysis from Bayesian pre-posterior decision analysis. Utilizing a principal model framework we show how the proposed approach is implemented with due consideration of the resilience governing characteristics and interdependencies between infrastructure systems, social/organisational systems, regulatory systems, ecological systems as well as anthropological and geological hazard systems.

Stabilization diagrams using operational modal analysis and sliding filters

This paper presents a filtering technique for doing effective operational modal analysis. The result of the filtering method is construction of stabilization diagram that clearly separates physical poles from spurious noise poles needed for unbiased fitting. A band pass filter is moved slowly over the entire frequency spectrum of the measured data, and poles in the band are identified for each new filter position. In this way all poles are identified many times, making the physical poles stand out to make them immediately identifiable. The technique is illustrated using the Time Domain Poly Reference(TDPR) system identification algorithm on simulated data.
Temperature Effects on Stiffness Moduli of Reservoir Sandstone from the Deep North Sea

We investigate the effect of testing temperature on the dynamic frame stiffness of quartz-bearing North Sea sandstone from depths of 5 km. We show that at low stress levels, the rock frame stiffens with increasing temperature and we propose an explanation for the controlling mechanisms. While equilibrating to atmospheric conditions, cooling and stress release of reservoir material can induce tensional forces in the rock frame leading to ruptures of the contact cement in the weakest grain contacts. The frame stiffness hence reduces, as the ruptures are permanent. However, a fraction of the in-situ stiffness can be restored by re-establishment of reservoir stress or temperature, but only as recovery of contact between ruptures and not as re-cementation. In literature, ruptures of contact cement are denoted as micro-cracks, strictly posing a bulk term, without distinguishing effects of stress from temperature. This is unfortunate and hence, we designed a testing program with the intention of separating and quantifying effects of temperature and stress, specifically for the sandstone material subject to this study.

The impact of reduction of doublet well spacing on the Net Present Value and the life time of fluvial Hot Sedimentary Aquifer doublets

This paper evaluates the impact of reduction of doublet well spacing, below the current West Netherlands Basin standard of 1000 - 1500 m, on the Net Present Value (NPV) and the life time of fluvial Hot Sedimentary Aquifer (HSA) doublets. First, a sensitivity analysis is used to show the possible advantage of such reduction on the NPV. The parameter value ranges are derived from West Netherlands Basin HSA doublet examples. The results indicate that a reduction of well spacing from 1400 to 1000 m could already improve NPV by up to 15%. This effect would be larger in more marginally economic HSA doublets compared to the West Netherlands Basin base case scenario. The possibility to reduce well spacing is supported by finite element production simulations, utilizing detailed facies architecture models. Furthermore, our results underline the necessity of detailed facies architecture models to assess the potential and risks of HSA doublets. This factor significantly affects doublet life time and net energy production of the doublet.
Thermodynamic Analysis of Chalk–Brine–Oil Interactions
The surface complexation models (SCMs) are used successfully for describing the thermodynamic equilibrium between the pure calcite surface (carbonate and calcium sites) and brine solutions. In this work, we show that the model parameters that are reported for the calcite–brine system are not applicable to the natural carbonates. We adjust the SCM reaction equilibrium constants by fitting the model to the ζ potential data that are reported for the pulverized Stevns Klint chalk. Then, we use the model, implemented in the PhreeqcRM geochemistry package coupled with a finite volume solver, to predict the breakthrough composition of different ions in the chromatographic experiments on the intact Stevns Klint chalk cores. Again, the model falls short in predicting the reactive transport of brine in a natural carbonate, implying that ζ potential data is not enough for optimizing the SCM model parameters for the reactive transport applications. We propose an optimization procedure that fits the coupled SCM–transport model parameters to the chromatographic (single-phase core flooding) data. The ζ potential measurements are implemented in the optimization scheme as nonlinear constraints. We then use the optimized model to study the thermodynamic equilibrium between the oil and chalk surfaces in the presence of different brine compositions, including the dissolution and precipitation of minerals. We represent the chalk–oil interactions by acid–base equilibrium reactions between the calcium and carbonate sites on the chalk surface and carboxylic acids and amine bases on the oil surface, respectively. Comparing the model results to a data set of the spontaneous imbibition experiments for chalk shows that the remaining oil saturation in the imbibition experiments is correlated with the number of bonds between the amine and carboxylate groups on the oil surface and the carbonate and protonated calcium on the chalk surface.

General information
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Organisations: Centre for oil and gas – DTU, Department of Chemical and Biochemical Engineering, CERE – Center for Energy Resources Engineering, Department of Chemistry
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Three-Dimensional poroelastic effects during hydraulic fracturing in permeable rocks

A fully coupled three-dimensional finite-element model for hydraulic fractures in permeable rocks is presented, and used to investigate the ranges of applicability of the classical analytical solutions that are known to be valid in limiting cases. This model simultaneously accounts for fluid flow within the fracture and rock matrix, poroelastic deformation, propagation of the fractures, and fluid leakage into the rock formation. The model is validated against available asymptotic analytical solutions for penny-shaped fractures, in the viscosity-dominated, toughness-dominated, storage-dominated, and leakoff-dominated regimes. However, for intermediate regimes, these analytical solutions cannot be used to predict the key hydraulic fracturing variables, i.e. injection pressure, fracture aperture, and length. For leakoff-dominated cases in permeable rocks, the asymptotic solutions fail to accurately predict the lower-bound for fracture radius and apertures, and the upper-bound for fracture pressure. This is due to the poroelastic effects in the dilated rock matrix, as well as due to the multi-dimensional flow within matrix, which in many simulation codes is idealised as being one-dimensional, normal to the fracture plane.

General information
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Organisations: Centre for oil and gas – DTU, Imperial College London
Authors: Salimzadeh, S. (Intern), Paluszny, A. (Ekstern), Zimmerman, R. W. (Ekstern)
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Towards the understanding of microbial metabolism in relation to microbial enhanced oil recovery

In this study, Bacillus licheniformis 421 was used as a model organism to understand the effects of microbial cell growth and metabolite production under anaerobic conditions in relation to microbial enhanced oil recovery. The bacterium was able to grow anaerobically on different carbon compounds, where n-alkanes were preferred over molasses as carbon source. The bacterium grew slowly when n-alkanes were used as carbon source, however, formation of emulsions and reduction of interfacial tension (IFT) were still observed. The bacterial cells were mainly present at the interface of the...
synthetic seawater medium and the n-alkanes. The bacterium produced lipopeptide lichenysin G which was detected both in the water and in the emulsion phase. We propose that the bacterial cells themselves or metabolites attached to the cell surface are the main players in the formation of emulsions and IFT reduction.

**General information**

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Organisations: Department of Chemical and Biochemical Engineering, CERE – Center for Energy Resources Engineering, Centre for oil and gas – DTU, Department of Systems Biology, Metabolomics Platform
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Web of Science (2009): Indexed yes
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Scopus rating (2005): SJR 0.75 SNIP 0.995
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A general procedure for estimating dynamic displacements using strain measurements and operational modal analysis

Measurement systems are being installed in more and more civil structures with the purpose of monitoring the general dynamic behavior of the structure. The instrumentation is typically done with accelerometers, where experimental frequencies and mode shapes can be identified using modal analysis and used in health monitoring algorithms. But the use of accelerometers is not suitable for all structures. Structures like wind turbine blades and wings on airplanes can be exposed to lightning, which can cause the measurement systems to fail. Structures like these are often equipped with fiber sensors measuring the in-plane deformation. This paper proposes a method in which the displacement mode shapes and responses can be predicted using only strain measurements. The method relies on the newly discovered principle of local correspondence, which states that each experimental mode can be expressed as a unique subset of finite element modes. In this paper the technique is further developed to predict the mode shapes in different states of the structure. Once an estimate of the modes is found, responses can be predicted using the superposition of the modal coordinates weighted by the mode shapes. The method is validated with experimental tests on a scaled model of a two-span bridge installed with strain gauges. Random load was applied to simulate a civil structure under operating condition, and strain mode shapes were identified using operational modal analysis.
A geometrically based method for predicting stress-induced fracture aperture and flow in discrete fracture networks

Modeling of fluid flow in naturally fractured reservoirs is often done through modeling and upscaling of discrete fracture networks (DFNs). The two-dimensional fracture geometry required for DFNs is obtained from subsurface and outcropping analog data. However, these data provide little information on subsurface fracture aperture, which is essential for quantifying porosity and permeability. Apertures are difficult to obtain from either outcropping or subsurface data and are therefore often based on fracture size or scaling relationships, but these do not consider the orientation and spatial distribution of fractures with respect to the in situ stress field. Using finite-element simulations, mechanical aperture can be modeled explicitly, but because changes in fracture geometry require renewed meshing and simulating, this approach is not easily integrated into subsurface DFN modeling workflows. We present a geometrically based method for calculating the shear-induced hydraulic aperture, that is, an aperture of up to 0.5 mm (0.02 in.) that can result from shear displacement along irregular fracture walls. The geometrically based method does not require numerical simulations, but it can instead be directly applied to DFNs using the fracture orientation and spacing distributions in combination with an estimate of the regional stress tensor and orientation. The frequency distribution of hydraulic aperture from the geometrically based method is compared with finite-element models constructed from five real fracture networks, digitized from outcropping pavements. These networks cover a wide range of possible geometries and spatial distributions. The geometrically based method predicts the average hydraulic aperture and equivalent permeability of fractured porous media with error margins of less than 5%.
Application of infrared thermography for temperature distributions in fluid-saturated porous media

Infrared thermography has increasingly gained importance because of environmental and technological advancements of this method and is applied in a variety of disciplines related to non-isothermal flow. However, it has not been used so far for quantitative thermal analysis in saturated porous media. This article suggests infrared thermographic approach to obtain the entire surface temperature distribution(s) in water-saturated porous media. For this purpose, infrared thermal analysis is applied with in situ calibration for a better understanding of the heat transfer processes in porous media. Calibration is achieved with a combination of invasive sensors which are inserted into the medium and non-invasive thermal sensors in which sensors are not inserted to measure temperatures but it works through the detection of infrared
radiation emitted from the surface. Thermocouples of relatively thin diameter are used to minimize the disturbance for flow. Thermocouples give the temperature values at specified positions inside the porous medium, and these values are compared with the values suggested by the infrared thermographic device at the same positions, in the calibration exercise. The calibration process was repeated for different temperatures and flow rates to get the temperature distributions of the whole material inside the system. This technique enables us to measure accurate two-dimensional temperature distributions, which is not possible by using thermocouples only. Continuous point heat sources at different flow rates and temperatures are studied experimentally. Additionally, it offers numerical simulations of the experiments utilizing a finite element-based model. A two-dimensional density and viscosity-dependent flow and transport model accounting for thermal dispersion is utilized to simulate the experimental results. Possible small heat losses from the surface are incorporated in the model according to the properties and thickness of the Plexiglass material used for the construction of the experiment tank. The numerical results agree well with the experimental observations.

Damping characteristics of a footbridge: Mysteries and truths
As a consequence of a paper presented by Michael Mistler at the VDI-Baudynamik-Tagung in Kassel, Germany, in April 2015, the authors checked the damping coefficients having been estimated for a footbridge in autumn 2014. Mistler stated that the critical damping ratio estimated from a halfpower bandwidth procedure to be dependent on frequency resolution for low frequency modes. Based on the data presented here this statement can be confirmed. The dependency on frequency resolution was found to be due to the leakage phenomenon on the spectral density. This fact may have been known in the academic world but not in the world of engineers applying OMA in practice. In this paper it is presented how
the leakage on the spectral density estimate is affecting the damping estimation through OMA based frequency domain identification. Finally the paper compares the damping estimated in the time and frequency domain from ambient tests, with the damping estimated from the free decays. Unfortunately, bias error on damping values determined from analyses in the frequency domain is worst on low frequency modes usually being the most important ones when dealing with a resonance problem in practice.

General information
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Organisations: Department of Mechanical Engineering, Solid Mechanics, Department of Civil Engineering, Section for Structural Engineering, Centre for oil and gas – DTU, RCI Dynamics
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Fracture Toughness Characterization of Honeycomb Core Sandwich Composites in Mode - I: A Comparative Study

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Organisations: Department of Mechanical Engineering, Solid Mechanics, Centre for oil and gas – DTU, Florida Atlantic University
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In Situ Techniques for the Investigation of the Kinetics of Austenitization of Suppermartensitic Stainless Steel
The austenitization and inter-critical annealing of X4CrNiMo16-5-1 (1.4418) supermartensitic stainless steel were investigated in-situ with synchrotron X-ray diffraction (XRD), dilatometry and differential scanning calorimetry (DSC) under isochronal heating conditions. Austenitization occurred in two stages: the austenitization started at approx. 600 °C, decelerated at approx. 700 °C at 60 to 75 v.% of transformed austenite, and first resumed after heating for approx. 100 °C. This plateau in the transformation curve was more dominant for faster heating rates. Intercritical annealing at 675 and 700 °C revealed, that austenite can to a certain extent be stabilized to room-temperature. There was good agreement for the transformation curves yielded by dilatometry and XRD. Some deviation occurred due to the different applied
heating principles, different temperature monitoring and the impact of surface martensite formation on the XRD measurement. The applicable temperature range for DSC as well as the close proximity of the $A_{c1}$- and the Curie temperature limited the usage of the technique in the present case.

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Organisations: Centre for oil and gas – DTU, Department of Mechanical Engineering, Materials and Surface Engineering, Helmholtz-Zentrum für Materialien und Energie, University of Rostock
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Microbial enhanced oil recovery—a modeling study of the potential of spore-forming bacteria

Microbial enhanced oil recovery (MEOR) utilizes microbes for enhancing the recovery by several mechanisms, among which the most studied are the following: (1) reduction of oil-water interfacial tension (IFT) by the produced biosurfactant and (2) selective plugging by microbes and metabolic products. One of the ways of bacterial survival and propagation under harsh reservoir conditions is formation of spores. A model has been developed that accounts for bacterial growth, substrate consumption, surfactant production, attachment/filtering out, sporulation, and reactivation. Application of spore-forming bacteria is an advantageous novelty of the present approach. The mathematical setup is a set of 1D transport equations involving reactions and attachment. Characteristic sigmoidal curves are used to describe sporulation and reactivation in response to substrate concentrations. The role of surfactant is modification of the relative permeabilities by decreasing the interfacial tension. Attachment of bacteria reduces the pore space available for flow, i.e., the effective porosity and permeability. Clogging of specific areas may occur. An extensive study of the MEOR on the basis of the developed model has resulted in the following conclusions. In order to obtain sufficient local concentrations of surfactant, substantial amounts of substrate should be supplied; however, massive growth of bacteria increases the risk for clogging at the well inlet areas, causing injectivity loss. In such areas, starvation may cause sporulation, reducing the risk of clogging. Substrate released during sporulation can be utilized by attached vegetative bacteria and they will continue growing and producing surfactant, which prolongs the effect of the injected substrate. The simulation scenarios show that application of the spore-forming bacteria gives a higher total production of surfactant and the reduced risk of clogging, leading to an increased period of production and a higher oil recovery.
Orbital calibration of the late Campanian carbon isotope event in the North Sea

A new record of carbon isotopes, nannofossil biostratigraphy, gamma-ray and Fe content variations is presented for the upper Campanian of the Adda-3 core, Danish Central Graben, North Sea. The studied interval provides a revision of previously assigned late Coniacian to early Santonian ages. New biostratigraphic data indicate a late Campanian age for the 60m thick studied interval. The Late Campanian Event (LCE) is well recorded by a 1.5 parts per thousand negative excursion in the bulk δ13C, along with two stepwise pre-exursion negative shifts (defining the pre-LCE). The amplitude of the LCE appears higher in the North Sea than in other areas as seen from the correlation to Germany, the UK and France. This correlation allows identification of a new 0.4 parts per thousand negative excursion (defined as the conica event). Fe and gamma-ray variations are used to calibrate the record with cyclostratigraphy. Fourteen 405 kyr cycles identified in the upper Campanian of Adda-3 can be correlated to North Germany. The compilation of previous results from North Germany and correlation to Adda-3 shows that the Boreal upper Campanian spans a total of 17 cycles each of 405 kyr; that is, 6.885myr. The duration of the LCE is estimated to be c. 1 myr at Adda-3 and in North Germany.

General information
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Number of pages: 14
The impact of different aperture distribution models and critical stress criteria on equivalent permeability in fractured rocks

Predicting equivalent permeability in fractured reservoirs requires an understanding of the fracture network geometry and apertures. There are different methods for defining aperture, based on outcrop observations (power law scaling), fundamental mechanics (sublinear length-aperture scaling), and experiments (Barton-Bandis conductive shearing). Each method predicts heterogeneous apertures, even along single fractures (i.e., intrafracture variations), but most fractured reservoir models imply constant apertures for single fractures. We compare the relative differences in aperture and permeability predicted by three aperture methods, where permeability is modeled in explicit fracture networks with coupled
fracture-matrix flow. Aperture varies along single fractures, and geomechanical relations are used to identify which fractures are critically stressed. The aperture models are applied to real-world large-scale fracture networks. (Sub)linear length scaling predicts the largest average aperture and equivalent permeability. Barton-Bandis aperture is smaller, predicting on average a sixfold increase compared to matrix permeability. Application of critical stress criteria results in a decrease in the fraction of open fractures. For the applied stress conditions, Coulomb predicts that 50% of the network is critically stressed, compared to 80% for Barton-Bandis peak shear. The impact of the fracture network on equivalent permeability depends on the matrix hydraulic properties, as in a low-permeable matrix, intrafracture connectivity, i.e., the opening along a single fracture, controls equivalent permeability, whereas for a more permeable matrix, absolute apertures have a larger impact. Quantification of fracture flow regimes using only the ratio of fracture versus matrix permeability is insufficient, as these regimes also depend on aperture variations within fractures.

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Organisations: Centre for oil and gas – DTU, Delft University of Technology
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Scopus rating (2011): SJR 3.018 SNIP 1.474 CiteScore 3.03
ISI indexed (2011): ISI indexed yes
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BFI (2010): BFI-level 2
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Aperture has a controlling impact on porosity and permeability and is a source of uncertainty in modeling of naturally fractured reservoirs. This uncertainty results from difficulties in accurately quantifying aperture in the subsurface and from a limited fundamental understanding of the mechanical and diagenetic processes that control aperture. In the absence of cement bridges and high pore pressure, fractures in the subsurface are generally considered to be closed. However, experimental work, outcrop analyses and subsurface data show that some fractures remain open, and that aperture varies even along a single fracture. However, most fracture flow models consider constant apertures for fractures. We create a stress-dependent heterogeneous aperture by combining Finite Element modeling of discrete fracture networks with an empirical aperture model. Using a modeling approach that considers fractures explicitly, we quantify equivalent permeability, i.e. combined matrix and stress-dependent fracture flow. Fracture networks extracted from a large outcropping pavement form the basis of these models. The results show that the angle between fracture strike and \( \sigma_1 \) has a controlling impact on aperture and permeability, where hydraulic opening is maximum for an angle of 15°. At this angle, the fracture experiences a minor amount of shear displacement that allows the fracture to remain open even when fluid pressure is lower than the local normal stress. Averaging the heterogeneous aperture to scale up permeability probably results in an underestimation of flow, indicating the need to incorporate full aperture distributions rather than simplified aperture models in reservoir-scale flow models.
The influence of facies heterogeneity on the doublet performance in low-enthalpy geothermal sedimentary reservoirs

A three-dimensional model is used to study the influence of facies heterogeneity on energy production under different operational conditions of low-enthalpy geothermal doublet systems. Process-based facies modelling is utilised for the Nieuwerkerk sedimentary formation in the West Netherlands Basin to construct realistic reservoir models honouring geological heterogeneity. A finite element based reservoir simulator is used to model the fluid flow and heat transfer over time. A series of simulations is carried out to examine the effects of reservoir heterogeneity (Net-to-Gross ratio, N/G) on the life time and the energy recovery rate for different discharge rates and the production temperature (Tmin) above which the doublet is working. With respect to the results, we propose a design model to estimate the life time and energy recovery rate of the geothermal doublet. The life time is estimated as a function of N/G, Tmin and discharge rate, while the
design model for the energy recovery rate is only a function of \( N/G \) and \( T_{min} \). Both life time and recovery show a positive relation with an increasing \( N/G \). Further our results suggest that neglecting details of process-based facies modelling may lead to significant errors in predicting the life time of low-enthalpy geothermal systems for \( N/G \) values below 70%.

**General information**
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Organisations: Centre for oil and gas – DTU, Delft University of Technology
Authors: Crooijmans, R. A. (Ekstern), Willems, C. J. L. (Ekstern), Nick, H. (Intern), Bruhn, D. F. (Ekstern)
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Scopus rating (2011): SJR 0.924 SNIP 1.976 CiteScore 1.9
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Scopus rating (2003): SJR 0.543 SNIP 1.035
Scopus rating (2002): SJR 0.556 SNIP 0.689
Scopus rating (2001): SJR 0.381 SNIP 0.861
Scopus rating (2000): SJR 0.398 SNIP 0.79
Projects:

**Big data at DHRTC**
Department of Applied Mathematics and Computer Science
Statistics and Data Analysis
Centre for oil and gas – DTU
Period: 15/09/2017 → 31/12/2017
Number of participants: 2
Project participant:
Jørgensen, Thomas Martini (Intern)
Schmidt, Karen Guldbæk (Intern)

**Numerical modelling of near wellbore flow**
Technical University of Denmark
Centre for oil and gas – DTU
Department of Applied Mathematics and Computer Science
Period: 01/07/2017 → 30/06/2020
Number of participants: 3
Phd Student:
Kadeethum, Teeratorn (Intern)
Supervisor:
Salimzadeh, Saeed (Intern)
Main Supervisor:
Nick, Hamid (Intern)

**Financing sources**
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU)
Project: PhD

**Risk Based Asset Management of subsurface wells against corrosion and scale**
Centre for oil and gas – DTU
Aalborg University
Period: 01/03/2017 → …
Number of participants: 1
Project participant:
Miraglia, Simona (Intern)

**Novel Productivity Enhancement Concept for a Sustainable Utilization of a Geothermal Resource**
Centre for oil and gas – DTU
**Operations and Maintenance Technology, CTR1**

The objective of this programme is to develop a Water Management Plan that addresses both operational performance and process development/design aspects related to facilities.

A close collaboration between researchers and a small Norwegian start-up leads to a new product, the ‘AlarmTracker’, ready for the control rooms of oil and gas platforms in 2019. The device supports the operator in making the right decisions in abnormal situations. Its objective is to secure a steady production, leading to an expected five percent increase of oil production.

Centre for oil and gas – DTU

Department of Electrical Engineering

Statistics and Data Analysis

Aalborg University

**Eldor Technology**

*Period: 15/02/2016 → 01/01/2020*

*Number of participants: 1*

*Acronym: CTR1*

*Number of related Ph.D. students: 5*

*Project participant:*

**Jørgensen, Thomas Martini (Intern)**

**3D imaging center**

Department of Physics

Neutrons and X-rays for Materials Physics

Department of Applied Mathematics and Computer Science

Image Analysis & Computer Graphics

Department of Energy Conversion and Storage

Imaging and Structural Analysis

Electrofunctional materials

Centre for oil and gas – DTU

*Period: 01/01/2016 → 01/01/2021*

*Number of participants: 14*

*Project participant:*

**Dahl, Anders Bjorholm (Intern)**

**Oddershede, Jette (Intern)**

**Trinderup, Camilla Himmelstrup (Intern)**

**Simonsen, Søren Bredmose (Intern)**

**Zheng, Yi (Intern)**

**Brink, Bastian (Intern)**

**Lauridsen, Torsten (Ekstern)**
Thydén, Karl Tor Sune (Intern)
Sanna, Simone (Intern)
Baier, Sina (Intern)
Bentzen, Janet Jonna (Intern)
Christensen, Anders Nymark (Intern)
Project Manager, organisational:
Gundlach, Carsten (Intern)
Project Manager, academic:
Poulsen, Henning Friis (Intern)

Relations
Related projects:
Alliance for Imaging and Modelling of Energy Applications
Publications:
- Powder embossing method for selective loading of polymeric microcontainers with drug formulation
- Crack Tip Flipping under Mode I Tearing: Investigated by X-Ray Tomography
- In-Situ X-ray Tomography Study of Cement Exposed to CO2 Saturated Brine
- Graphite nodules in fatigue-tested cast iron characterized in 2D and 3D
- Scene reassembly after multimodal digitization and pipeline evaluation using photorealistic rendering
- From concept to in vivo testing: Microcontainers for oral drug delivery
- Synthesis and characterization of Fe–Ni/γ-Al2O3 egg-shell catalyst for H2 generation by ammonia decomposition
- Microstructure and micromechanics of the heart urchin test from X-ray tomography
- Surface Detection using Round Cut
- Characterization of graphite nodules in thick-walled ductile cast iron
- High-Performance Microchanneled Asymmetric Gd0.1Ce0.9O1.95-δ-La0.6Sr0.4FeO3-δ-Based Membranes for Oxygen Separation
- Project

Activities:

Pilot Demonstration of Alarm Management in Oil & Gas Operations. - Decision Support from Functional Modelling.
Period: 14 Nov 2017 → 15 Nov 2017
Thomas Martini Jørgensen (Guest lecturer)
Department of Applied Mathematics and Computer Science
Statistics and Data Analysis
Centre for oil and gas – DTU
Degree of recognition: International
Documents:
DHRTC-Presentation-abstracts
Links:
http://www.oilgas.dtu.dk/english/-/media/Andre_Universitetsenheder/Oilgas_ny/Tech-conf-17/DHRTC-Presentation-abstracts.ashx?la=da

Related organisation
Pilot Demonstration of Alarm Management in Oil & Gas Operations. - Decision Support from Functional Modelling.
Jørgensen, T. M. (Guest lecturer)
14 Nov 2017 → 15 Nov 2017
Activity: Talks and presentations › Conference presentations

Applying LCA in decision making- the need and the future perspective
Period: 10 May 2017
Yan Dong (Speaker)
Simona Miraglia (Other)
Stefano Manzo (Other)
Stylianos Georgiadis (Other)
Hjalte Jomo Danielsen Sørup (Other)
Elena Boriani (Other)
Tine Hald (Other)
Sebastian Thöns (Other)
Michael Zwicky Hauschild (Other)

Department of Management Engineering
Quantitative Sustainability Assessment
Centre for oil and gas – DTU
Transport DTU
Transport Modelling
Department of Applied Mathematics and Computer Science
Statistics and Data Analysis
Department of Environmental Engineering
Urban Water Systems
National Food Institute
Research Group for Genomic Epidemiology
Department of Civil Engineering
Section for Structural Engineering

Documents:
AbstraApplying LCA in policy deciison making_Final
Links:
https://brussels.setac.org/welcome/

Related event

SETAC Europe: 27th Annual Meeting – Environmental Quality Through Transdisciplinary Collaboration
07/05/2017 → 13/07/2017
Brussels, Belgium
Activity: Talks and presentations › Conference presentations

Making sense of Big Data
Period: 24 Apr 2017
Thomas Martini Jørgensen (Guest lecturer)
Department of Applied Mathematics and Computer Science
Statistics and Data Analysis
Centre for oil and gas – DTU

Description
Talk given at internal Digitalization workshop within Maersk Oil
Degree of recognition: Local

Related organisation

Making sense of Big Data
Jørgensen, T. M. (Guest lecturer)
24 Apr 2017
Activity: Talks and presentations › Talks and presentations in private or public companies and organisations

Making sense of big data for Produced Water Treatment
Period: 17 Nov 2016
Thomas Martini Jørgensen (Invited speaker)
Fracture Toughness Characterization of Honeycomb Core Sandwich Composites in Mode - I: A Comparative Study
Vishnu Saseendran (Speaker)
Christian Berggreen (Lecturer)
Leif A. Carlsson (Lecturer)
Department of Mechanical Engineering
Solid Mechanics
Centre for oil and gas – DTU

Description
The aim of this paper is to experimentally investigate face/core fracture toughness and disbond propagation in a honeycomb core sandwich using two contemporary test methods - single cantilever beam (SCB) and double cantilever beam uneven bending moments (DCB-UBM). These test methods will be performed in mode-I conditions to allow comparison.
Degree of recognition: International

Related event
11th International Conference on Sandwich Structures (ICSS-11)
20/03/2016 → 22/03/2016
Fort Lauderdale, FL, United States
Activity: Talks and presentations › Conference presentations

Biorefinery Öresund Conference 'Biorefining from raw material to high value products'
Period: 1 May 2012 → 30 Apr 2015
Peam Cheali (Speaker)
Krist V. Gernaey (Speaker)
Gürkan Sin (Speaker)
Department of Chemical and Biochemical Engineering
CAPEC-PROCESS
Centre for oil and gas – DTU

Description
Poster presentation.

Related event
Biorefinery Öresund Conference 'Biorefining from raw material to high value products'
18/09/2013 → …
Ørestad, Denmark
Activity: Talks and presentations › Conference presentations
Press clippings:

Interview with research talents
Frank Nießen
25/05/2018

Description
Department of Mechanical Engineering, Materials and Surface Engineering, Centre for oil and gas – DTU

Media contribution (1)

Interview with research talents
25/05/2018
The Danish Hydrocarbon Research and Technology Centre (International), Denmark, Web
The Danish Hydrocarbon Research and Technology Centre
Frank Nießen
Centre for oil and gas – DTU, Department of Mechanical Engineering, Materials and Surface Engineering
Press / Media

Experiments on Supermartensitic Stainless Steel in Berlin
Frank Nießen
17/10/2017

Description
http://www.oilgas.dtu.dk/english/press/nyhedsbase/2017/10/experiments-on-supermartensitic-stainless-steel-in-berlin?id=ca0339b0-010a-4c31-89e7-d29d29a609e3

Subject
DHRTC researchers conduct in-situ stress measurements at the synchrotron facility BESSYII in Berlin in an effort to find the microstructure of supermartensitic stainless steels most suited to withstand high load and large degrees of deformation.
Department of Mechanical Engineering, Materials and Surface Engineering, Centre for oil and gas – DTU

Media contribution (1)

Experiments on Supermartensitic Stainless Steel in Berlin
17/10/2017
The Danish Hydrocarbon Research and Technology Centre (International), Denmark, Web
The Danish Hydrocarbon Research and Technology Centre
http://www.oilgas.dtu.dk/english/press/nyhedsbase/2017/10/experiments-on-supermartensitic-stainless-steel-in-berlin?id=ca0339b0-010a-4c31-89e7-d29d29a609e3
DHRTC researchers conduct in-situ stress measurements at the synchrotron facility BESSYII in Berlin in an effort to find the microstructure of supermartensitic stainless steels most suited to withstand high load and large degrees of deformation
Frank Nießen
Department of Mechanical Engineering, Materials and Surface Engineering, Centre for oil and gas – DTU
Press / Media