A Scientific Basis for the Development of the Next Generation of Biodust Burners

Johansen, Joakim Myung; Jensen, Peter Arendt; Clausen, Sønnik; Fateev, Alexander; Nielsen, Karsten Lindorff; Thomsen, J.; Gadsbøll, Rasmus Østergaard; Mitchell, R.; Weber, R.; Mancini, M.

Publication date: 2015

A Scientific Basis for the Development of the Next Generation of Biodust Burners


aTechnical University of Denmark, bStanford University, cClausthal University of Technology, dVattenfall, eDONG Energy, fBurmeister and Wain Energy

Devolatilization kinetics play an important role especially when considering thermal conversion of high volatile content biomass in pulverized fuel combustion. This study combines small scale laminar flow conversion experiments with corresponding computational fluid dynamic (CFD) calculations making it possible to evaluate the devolatilization kinetics taking the particle temperature history into account, cf. figure 1.

Effective quenching and well defined fuel trajectories makes it possible to collect partially converted particles at residence times in the order of milliseconds. A scarce necessity when fitting conversion models. Using a global, single step, first order Arrhenius type model to describe devolatilization leads to temperature history dependent kinetic parameters:

\[ A = 625 \text{ s}^{-1} \]
\[ E_a = 6 \text{ kJ} \times \text{mol}^{-1} \]

*Results of preliminary predictions. Parameters are subject to change in conversion times.

Resulting in a conversion fit, cf. figure 3.

Combining measurement and simulation results from lab-, bench-, and full-scale systems provides a common thread in developing guidelines for novel burner designs.

Scale-up issues are known to be challenging and thus making the balance between accuracy and complexity difficult.

This study aims to provide a common thread through CFD simulations all the way from single particle behavior to industrial application. Evaluation of the validity of small-scale result extrapolation is made by gradual experimental scale-up from lab- to bench-scale. Using a 15 kW drop tube reactor the devolatilization kinetics derived in lab-scale are validated by comparing measurements to the corresponding CFD simulations.

The devolatilization kinetics are validated in a 15 kW drop tube reactor, comparing measurements with CFD predictions.

Full-scale measurements are conducted at Amager (318 MWth) and Herning (288 MWth) power stations in Denmark. Both power stations are 100 % biodust fueled (primarily woody fuels) with 30 MW individual front wall mounted, low NOx, swirl stabilized burners. A series of analytical methods have been applied, thoroughly characterizing the full-scale flames.

In-flame measurements:
- Gas phase temperatures (FTIR and suction pyrometry)
- Gas phase chemical composition including radical concentration quantification (UV/IR)
- Seeded laser doppler anemometry (LDA) velocimetry measurements in the axial and tangential direction
- Particle extraction

Additional analyses
- High speed imaging in the infrared spectrum
- Video imaging
- Particle cloud surface temperature assessment (two-line thermometry)
- Particle cloud intrusion and trajectory (IR imaging)

Summary
A set of simple kinetic parameters for biomass devolatilization has been derived and validated by tying together experimental setups of different thermal throughputs by measurements and CFD simulations.

Scaling up combustion processes for qualitative trend assessment all the way from single particle behavior to full-scale industrial application is well on the way.

Acknowledgement
The Danish Council for Strategic Research is gratefully acknowledged for the funding.

Contact
Joakim M. Johansen, PhD-Student, jioha@kt.dtu.dk