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Publication date:
2015

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Citation (APA):

Johansen, J. M., Jensen, P. A., Clausen, S., Fateev, A., Nielsen, K. L., Thomsen, J., ... Glarborg, P. (2015). A Scientific Basis for the Development of the Next Generation of Biodust Burners. Poster session presented at 35th International Symposium on Combustion , San Francisco, United States.

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

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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 reactor 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.

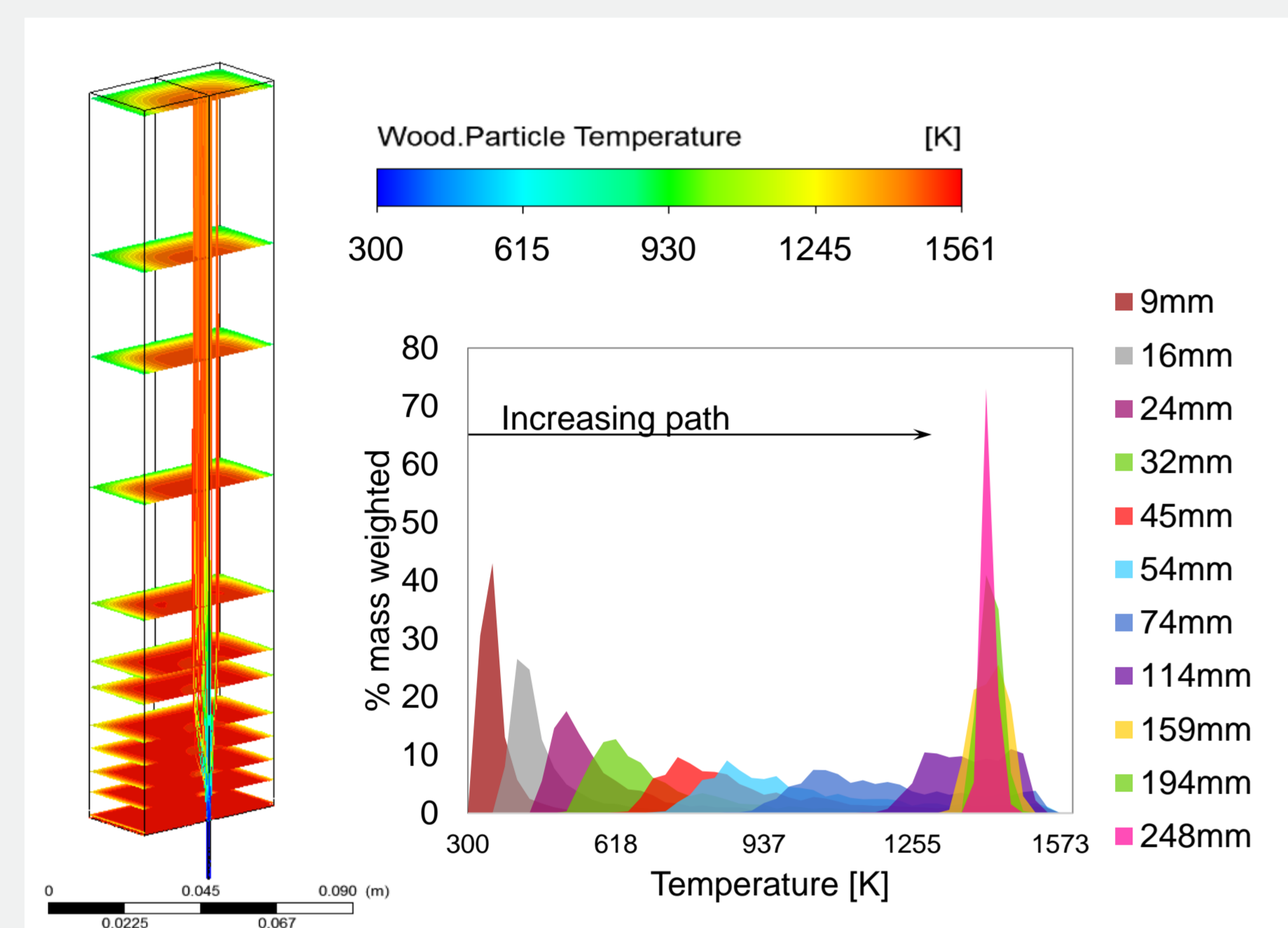


Figure 1: Gas phase and particle temperature history used to derive the intrinsic devolatilization kinetics at heating rates in the order of 10^5 K/s.

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:

$$A = 625 \text{ s}^{-1}$$

$$E_a = 6 \text{ kJ} \times \text{mol}^{-1}$$

*Result of preliminary predictions. Parameters are subject to change in consecutive iterations.

Resulting in a conversion fit, cf. figure 3.

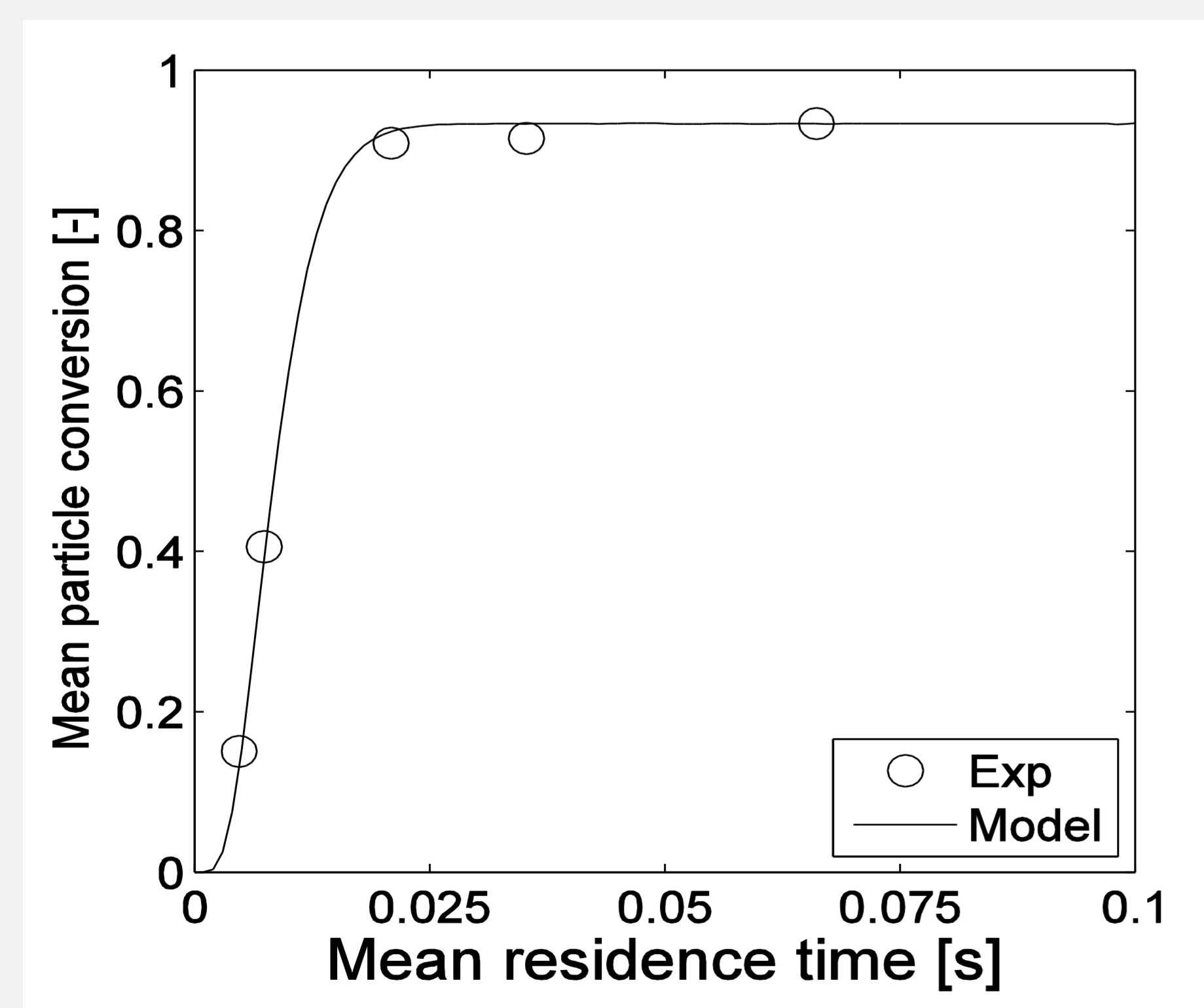
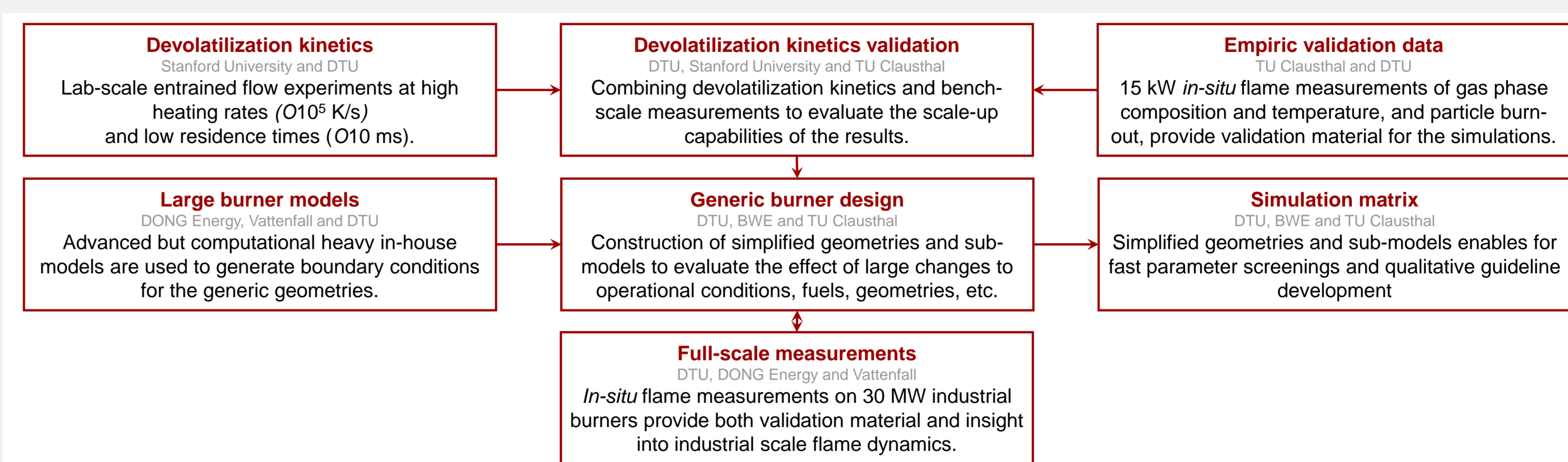


Figure 2: Kinetic fit of a global, single step, first order Arrhenius type equation describing the devolatilization of woody biomass as high heating rates and low residence times.



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**.

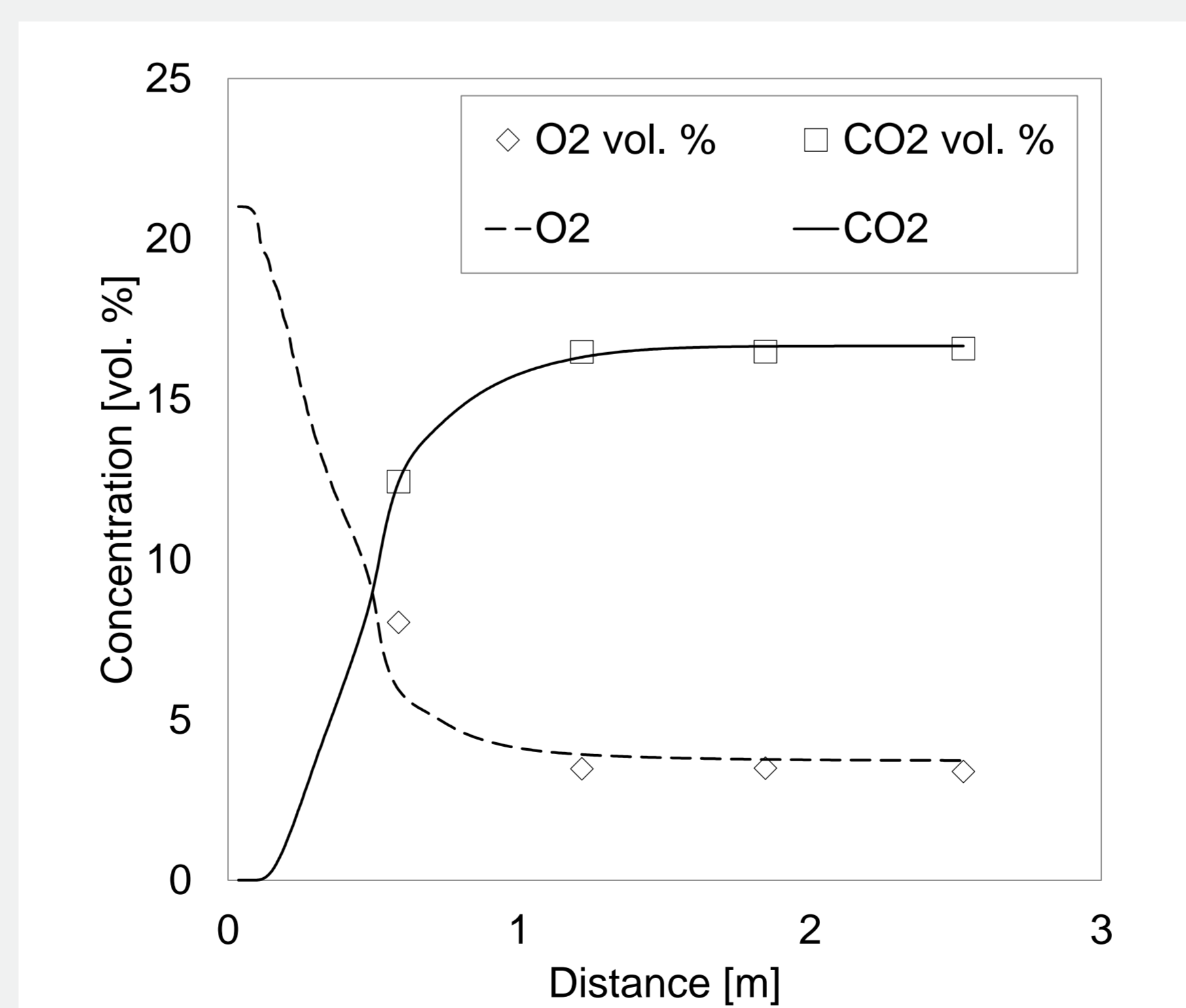


Figure 3: Comparison of oxygen and carbon dioxide measurements and CFD simulation results using the devolatilization derived from figure 2.

Full-scale measurements are conducted at Amager (318 MW_{th}) and Herring (288 MW_{th}) power stations in Denmark. Both power stations are 100 % biodust fueled (primarily woody fuels) with 30 MW individual front wall mounted, low NO_x, 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 through puts 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.

Acknowledgment

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

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