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DTU Chemical Engineering
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An introduction to the work behind the development of the next generation of swirl stabilized burners for dedicated biodust combustion. A compilation of lab-scale derived chemical kinetics, CFD simulations, and full-scale measurements.

Background

Thermal conversion of biomass into heat and power is arguably the single most efficient way of utilizing the energy bound in any source of biomass. Its existence is required in order to balance out the fluctuating production from wind mills and other alternative sources and to provide district heating.

Objectives

This work aims to establish a scientific basis for the development of a new generation of biomass burners designed to facilitate high electrical efficiency and fuel flexibility under stable operating conditions.

Content

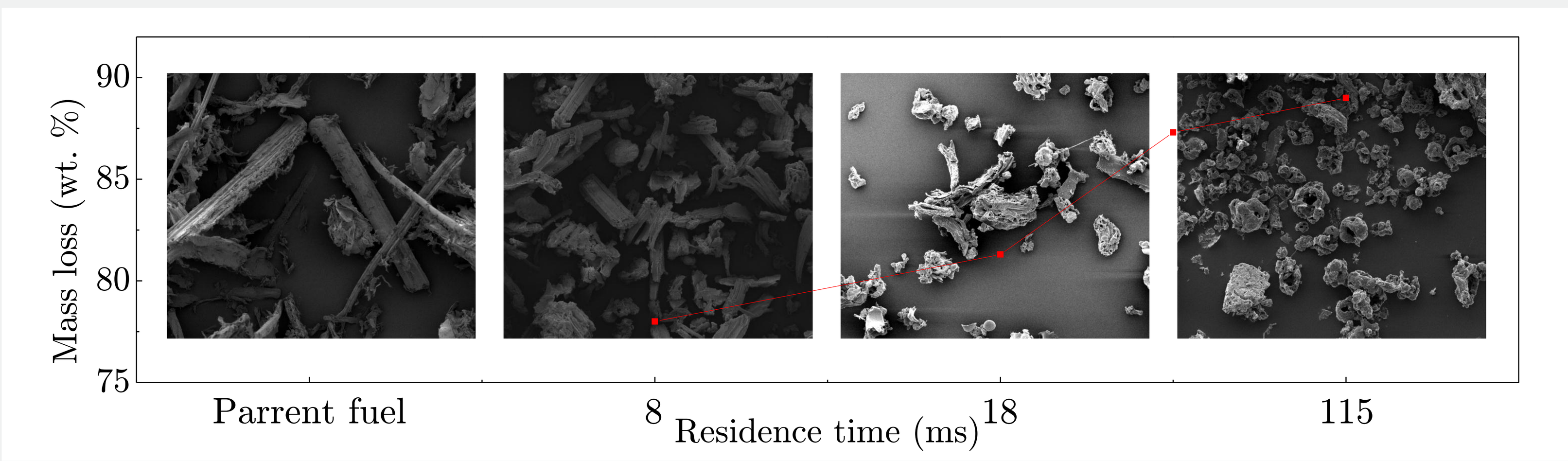
Classic Engineering Study
- Particle morphology development
- Reaction kinetics

CFD Modeling
- Simplified sub-model structure and burner geometry
- Qualitative trend assessment

Full-Scale Campaigns
- Flame response to significant changes in process parameters

Classical Engineering Study

Understanding the particle development, both physically and chemically, is a key aspect when shifting from conventional coal to biomass. Such information are derived from laboratory experiments at heating rates in the order of 10^4-10^5 K/s. The development in particle morphology is followed by SEM and both devolatilization and char burn-out kinetics are derived using TGA.



Following the particle development and mass loss of pulverized miscanthus as the devolatilization progresses in a lab-scale laminar entrained flow reactor.

Full-Scale Campaigns

The full-scale campaigns provide much needed information on in-flame conditions during dedicated biodust operation. Flame mapping includes: gas phase temperatures, chemical composition using probe techniques while estimations of particle cloud velocity, surface temperature, and flame stability is assessed from optical observations in both the VIS and IR spectrum. The flame responses to significant changes in the operational conditions have been monitored.

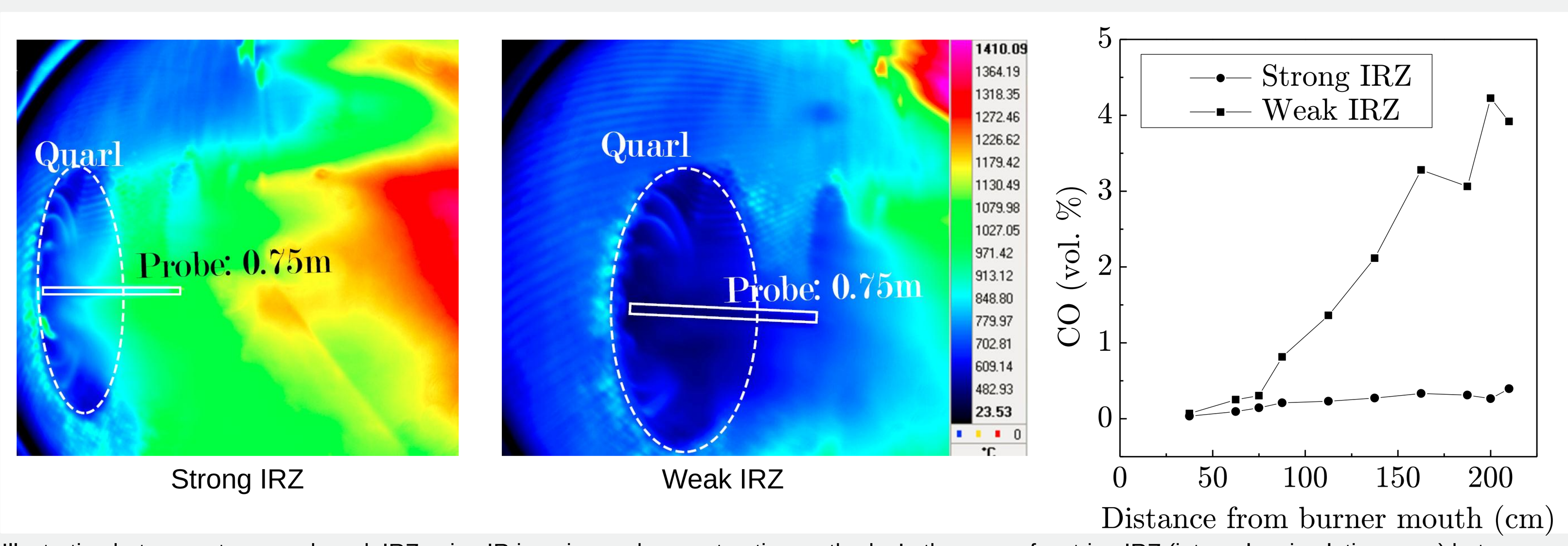
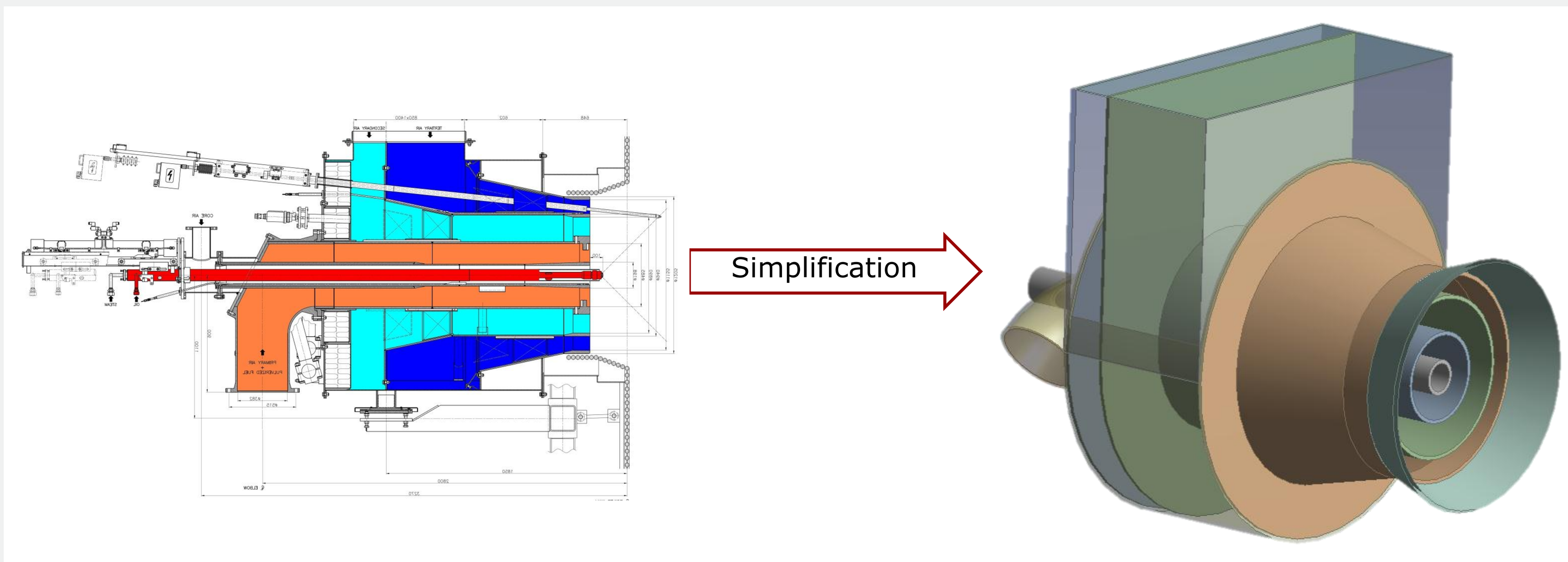


Illustration between strong and weak IRZ using IR imaging and gas extractive methods. In the case of a string IRZ (internal recirculation zone) hot gases are drawn all the way back to the quarl and the production of pyrolysis products e.g. CO is minimized. Vice versa a large production of pyrolysis gases can be observed as well as cold particles allowed to penetrate far into the flame in the case of a weak IRZ.

Computational Fluid Dynamics (CFD) Modeling

Generic burner geometries and simplified sub-model construction are the key aspects of the modeling. Acknowledging that the properties of biomass are highly diverse, these models are used for qualitative trend assessments from which general design guidelines can be derived.



Simplification of complex burner designs makes the CFD simulations more diverse and thus generally applicable to R&D.

Summary

The kinetics derived from the classical engineering study are used to simulate the devolatilization and char burn-out phases in the CFD model. Likewise, the study on morphology development will be used to estimate suitable sub-routines, e.g. effective drag coeffcients. The full-scale campaign is used to evaluate the results of the generic CFD models. As the qualitative trends can be reproduced, the CFD models can be used to extend the experimental matrix and facilitate process optimization.

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