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Numerical Analysis of the Iron Dust Bunsen setup

T. Hazenberg[1]*, A. Scholtissek[1], C. Hasse[1]
*Lead presenter: hazenberg@stfs.tu-darmstadt.de
[1]Technical University of Darmstadt, Simulation of reactive Thermo-Fluid Systems, Germany

In recent years, the combustion of iron has gained significant attention. Iron can be combusted and reduced in a renewable energy cycle [1]. Thus, iron is a promising candidate as a future zero-carbon energy carrier. Still, important physical aspects require a deeper understanding, such that iron combustion can be used effectively for energy supply.

In the metal fuel community, a major challenge is validating existing models. Previous studies have successfully validated the burn time of a single particle [2, 3]. However, flames have proven to be more challenging. Iron dust flames are notoriously difficult to stabilize. While several 1D models have been developed on a sound basis [2, 3, 4], their burning velocity prediction is severely lower than that observed in experiments. An underprediction of the burning velocity is surprising, as particles burn in the diffusion-limited regime, i.e., can not oxidize any faster, and the models have been validated to predict this accurately.

In this presentation, our group's recent results regarding iron dust Bunsen flames are shown. 3D simulations are conducted of the experimental iron dust burner by Fedoryk et al. [5]. The flame structures of these 3D flames are analyzed and compared against 1D flames. Several differences in the flame structure are identified, which enhance the burning velocity. Using several methods, the burning velocity is extracted from the numerical simulations and compared to the experimental results. This comparison provides satisfactory agreement and confidence in the model for further analysis. In a second analysis, the stability of the numerical flame is assessed by applying abrupt changes in particle loading. This analysis shows that the numerical flame is remarkably stable, in contrast to the experiment. Hence, these findings suggest that further research will be necessary, and they highlight the importance of well-defined experimental target flames such as the iron dust Bunsen flame.

References

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