

A pseudo-spectral approach for variable-density flows with reacting iron particles

Gabriel Thäter^{1*}, Bettina Frohnapfel¹, Oliver T. Stein², Maurizio Carbone³

*Lead presenter: gabriel.thaeter@kit.edu

¹ Institute of Fluid Mechanics, Karlsruhe Institute of Technology, Karlsruhe

² Engler-Bunte-Institute, Karlsruhe Institute of Technology, Karlsruhe

³ Istituto dei Sistemi Complessi, CNR, Rome

We present a numerical method for solving the Navier–Stokes equations under the low Mach number assumption for carrier-phase direct numerical simulations of iron particle cloud combustion. The approach combines the simplicity of a pseudo-spectral Fourier method to effectively resolve small-scale turbulence and the accuracy of the Non-Uniform Fast Fourier Transform (NUFFT) [1] for efficient two-way coupling between fluid fields and the Lagrangian particle phase. The turbulent velocity field transports reacting inertial particles, which evolve according to the FOSK model [2], and two active scalar fields representing the fluid temperature and oxygen concentration. The particle reaction induces localized changes in the temperature and oxygen mass fraction fields, generating localized density changes and divergent fluid motion. We detail the numerical scheme and explore flame front propagation in turbulent flows seeded with iron particles ignited on an initially planar surface. By combining previous studies on flame propagation in discrete particle clouds [3] and the interactions between turbulence and igniting particles [4], we characterize the velocity and wrinkling of the turbulent two-phase flame front.

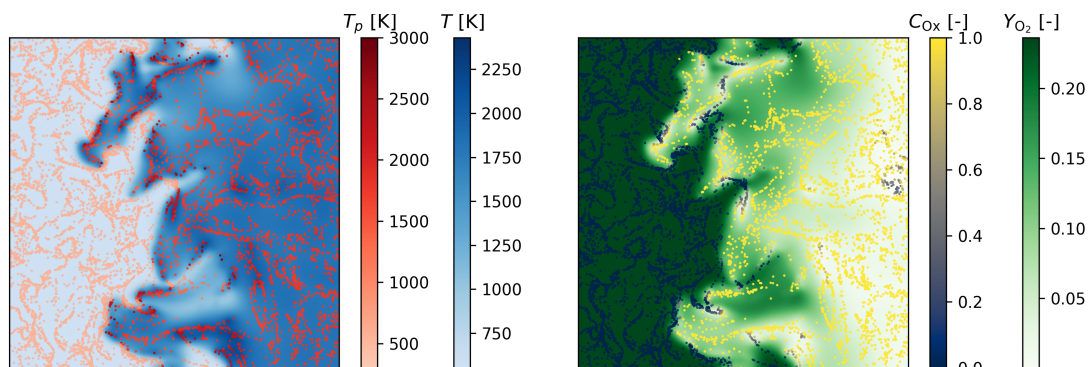


Figure 1: Snapshot of a particle cloud flame in homogenous turbulence. Left: Fluid (T) and particle temperature (T_p). Right: Particle oxidation progress C_{Ox} and oxygen mass fraction Y_{O_2} .

References

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