Dynamics of an autocatalytic reaction front: effects of imposed turbulence and buoyancy-driven flows

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Thin flame dynamics in a turbulent flow remains debated, with various parameterizations proposed for the typical flame propagation velocity. According to the classical Damköhler's model based on Huygens' principle, a flame front should advance at a constant velocity normal to the interface between reactants and products, with a turbulent acceleration induced by the wrinkling and surface increase of the interface. However, combustion experiments often deviate from this model due to intertwined thermal and turbulent effects, complicating flame acceleration characterization.

In this study, we use an autocatalytic reaction that generates a thin reactive front in an aqueous medium, enabling clearer isolation of turbulence effects. Using oscillating grids to generate turbulence in a closed tank, we examine two configurations: a single-grid setup with a spatially decaying turbulence and a dual-grid system with in the middle, a nearly homogeneous, isotropic turbulence. Particle Image Velocimetry and Laser Induced Fluorescence measurements capture both the velocity field and the front propagation, revealing two different regimes: the expected Huygens' propagation regime (Figure 1a), but also a reactive mixing regime (Figure 1b), where the turbulent advection of the products inside the reactants initiates multiple, dispersed reaction locations. Additionnally, we show that the small density difference between reactants and products plays a crucial role in the front dynamics. This work advances our understanding of autocatalytic fronts in turbulence, emphasizing the critical interplay between chemical kinetics and flow dynamics.

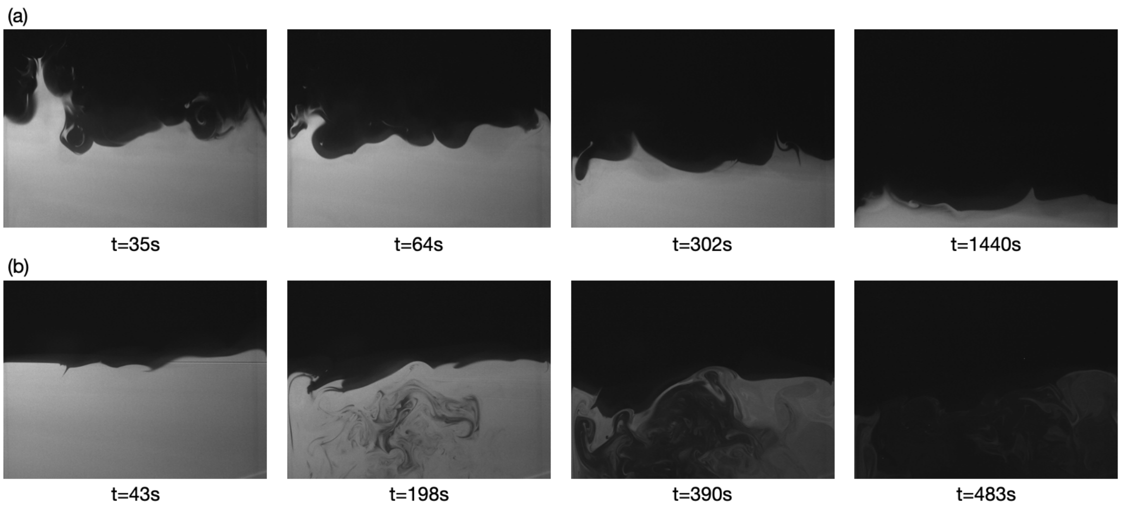

Figure 1: Snapshots of Laser Induced Fluorescence images captured at different times. The images are 20 cm wide, with $t = 0$ marking the start of grid oscillations. The grid is positioned approximately 1 cm from (a) the top of the images (in the products) and (b) the bottom of the images (in the reactants).

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