Experimental and numerical study of small-scale turbulent mixing in a T-shaped mixer

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Many chemical engineering processes rely on the rapid mixing of two fluid streams containing dissolved reactants. The mixing rate is primarily governed by the contact area between the fluids and the mass diffusion coefficient, D. In practical applications, most mixing devices are designed to generate highly turbulent flows, where multi-scale eddies significantly enhance fluid contact and accelerate mixing [1]. Despite advances in turbulence modelling, our understanding of small-scale turbulent mixing remains limited. This poses significant challenges for predicting mixing-sensitive continuous reactions in chemical engineering with high accuracy.

We investigate the smallest scales in turbulent scalar field mixing, known as the Batchelor scale. To achieve this, an upscaled T-shaped mixer has been designed, and simultaneous particle image Velocimetry (PIV) and planar laser-induced fluorescence (PLIF) measurements are conducted at various cross-sections of the setup. The simultaneous use of PIV and PLIF allows us to resolve both the velocity and scalar fields simultaneously, enabling us to correlate small-scale structures in the scalar field with the velocity gradient. We conduct measurements starting from low Reynolds numbers up to moderate values up to Re=2000 for which we can the finest scalar structures within the viscous-convective subrange of turbulent scalar mixing [2]. Complementary DNS of the T-mixer are performed using NEK5000 to validate the experimental setup and measurements [3]. We characterize the decay of turbulence along the main channel and that the scalar dissipation and dissipation decay as power laws, as in decaying turbulence.

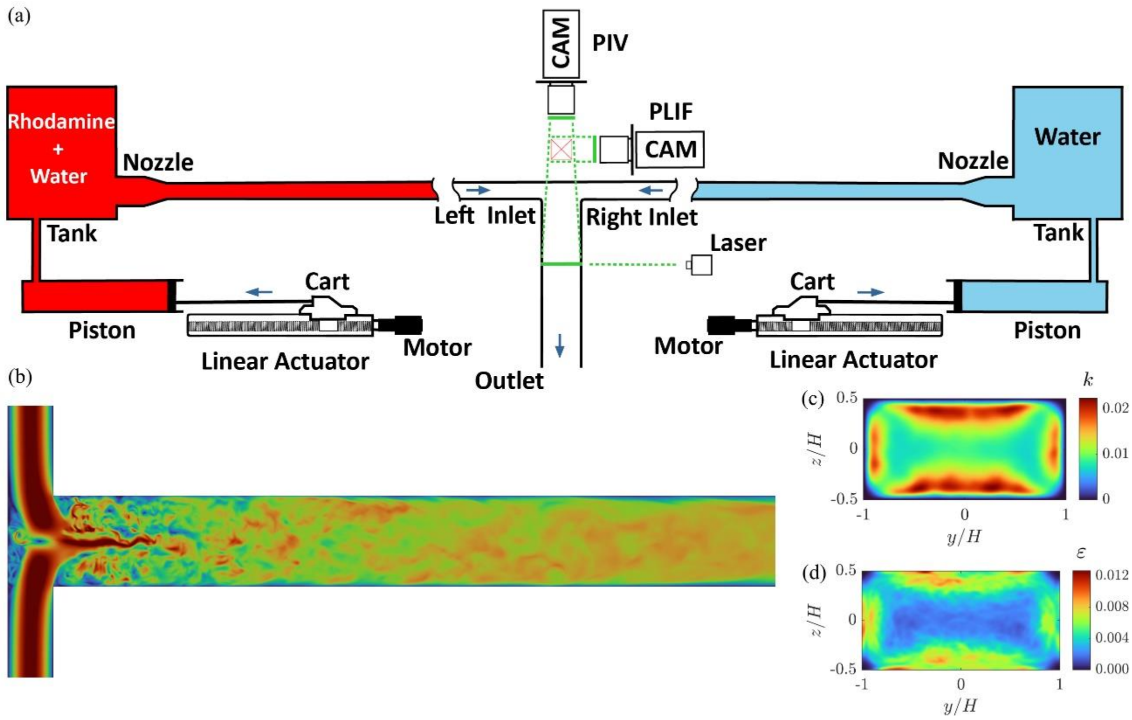

Figure 1: (a) Schematic of the experimental setup for the simultaneous PIV and PLIF (b) Colormap of the velocity magnitude from DNS of T-mixer at Re=1500 (c) cross-sectional turbulent kinetic energy in the outlet channel at *x/H=16* (d) turbulent dissipation rate at the same cross-section.

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[1] Dimotakis, *Annual Review of Fluid Mechanics*, **Vol 37** (2005)
[2] Batchelor, *Journal of Fluid Mechanics*, **Vol 5** (1959)
[3] Nek5000, Version 19.0, 2016, Argonne National Laboratory, Illinois.