Quantification of laminar mixing performance using laser-induced fluorescence

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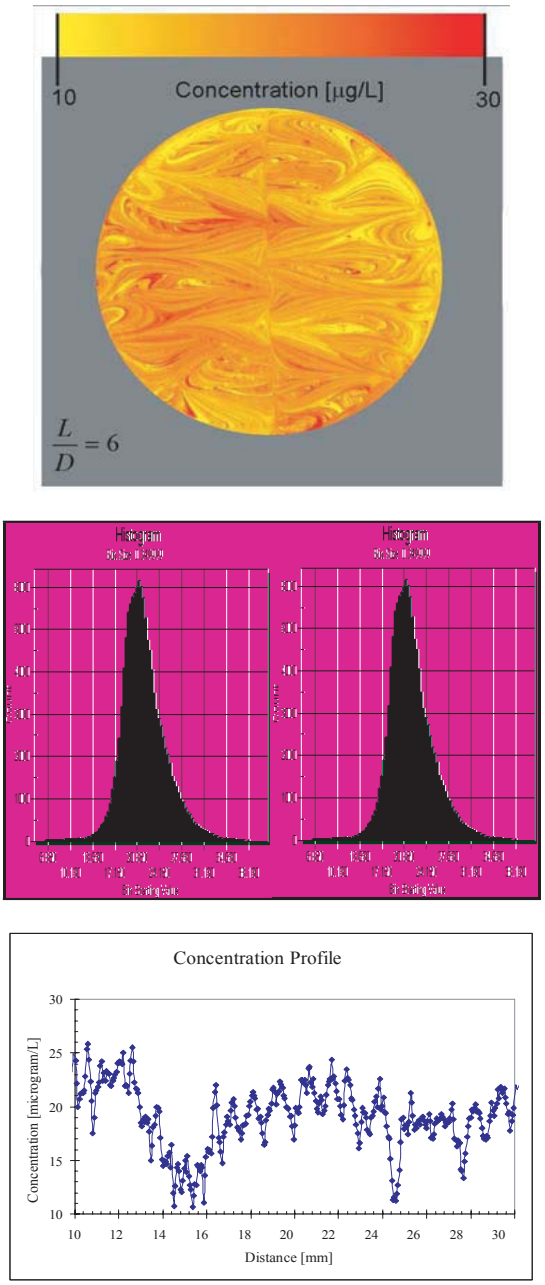
PLIF measurements of mixing appear across a range of disciplines (including combustion diagnostics, fundamental turbulence and fluid mechanics, microfluidics, environmental engineering, contaminant hydrogeology, and industrial mixing processes) for a range of different flow applications (such as turbulent flow analysis, laminar mixing, IC engine flows, micron scale flows, wake flows, and injector flows). Although the measurement goals vary according to the specific application, the measured parameters are all similar in that they act as indicators of the extent or efficiency of a mixing process.

PLIF measurements of concentration were performed at varying distances downstream of a commercial static mixing device (Sulzer SMX mixer). The mixer was positioned in a vertical pipe with fluids flowing upward through the device. Two unmixed fluid streams were introduced immediately below the static mixer. One fluid stream was a glucose solution seeded with Rhodamine 6G as a fluorescent tracer species, while the other stream was unseeded glucose solution. A tracer concentration of 50 µg/L was used. Separate measurements were performed to determine the binary diffusion coefficient between the unseeded fluid stream and the stream seeded with the Rhodamine 6G tracer, for comparison to CFD simulations of the mixing process. Rhodamine 6G was chosen as the tracer species due to the relatively high fluorescence yield, as well as the broad absorption feature with a peak near 525nm (near the readily available 532nm YAG harmonic) and emission feature with a peak near 560nm.

The raw PLIF images were corrected for extraneous background signals and were processed using calibration images captured at uniform concentration values. Because the dominant structures in this flow were preferentially oriented parallel to the limiting dimension (perpendicular to the light sheet plane), the spatial resolution of the PLIF measurement was increased beyond the 400 mm thickness of the laser light sheet. Fluid layers as small as 200 mm to 300 mm were observed. The non-dimensional mixing length, L/D, was varied from 4 to 8, and changes in the concentration field were examined. The coefficient of variation decreased from 0.46 to 0.073 as the mixing length increased from 4 to 8, and the minimum thickness of the fluid layers decreased from above 1 mm to less than 400 mm.

L/D	Mean Con. [µg/L]	Standard Deviation [µg/L]	CoV
4	20.7	9.46	.46
6	21.9	3.37	.15
8	22.3	1.62	.073



PLIF measurement of the concentration field (top), concentration histogram (middle), and profile graph of concentration for the L/D = 6 case. Table showing effect of varying the mixing length (L/D) on the spatial concentration distribution (left).