Skin friction acquisition of an impinging jet-flat plate setup using temperature-sensitive paint (TSP)

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Surface skin friction fields have historically been identified as one of the most challenging surface quantities to measure. While numerous methods have been used in past research, challenges with spatial/temporal resolution and sensitivity to local conditions have hindered their broader application in experimental work. One emergent technique that shows promise to mitigate some of these issues is the use of temperature-sensitive paint (TSP) imaging. TSP emits varying intensities of light depending on local surface temperature, with imaged intensities converted to a continuous surface temperature field using known calibration curves. The surface temperature field can then be converted to skin friction using a variety of approaches. This presentation provides an overview of the theory and application of TSP on a flat plate-impinging jet setup, including error mitigation and considerations for broader experimental applications.

Experiments were conducted using a perpendicular impinging jet setup at the University of Toronto Institute for Aerospace Studies. A 3 mm diameter jet nozzle was affixed 60 mm off the plate surface, providing a nozzle diameter-to-offset ratio of H/D = 20. A jet exit velocity of 28 m/s provides a Reynolds number of $Re_D = 5.7 \times 10^3$. A 100 x 120 mm aluminum plate coated in a Europium-based TSP was mounted below the jet, illuminated by a UV LED light and imaged by a LaVision sCMOS camera fitted with a 620/60 nm bandpass filter. TSP images were acquired across a range of ambient conditions, camera orientations and sampling frequencies, allowing for the comparison of data quality across different acquisition setups.

Observed surface temperature behaviour was largely consistent with past experimental work and theoretical predictions. Data processing and averaging methods from existing TSP literature provided adequate filtering of surface and setup imperfections. Signal-to-noise was observed as most sensitive to surface heat flux, supporting the presence of embedded model heating in broader TSP research. Increasing noise from smaller camera incidence angles and sampling time was observed, yet could be mitigated through temporal and spatial averaging across multiple image sets. Skin friction fields extracted from surface temperature data showed consistency with past experimental results, with similar agreement near the impingement centre and deviation from theoretical skin friction magnitude at large radial distances seen across all experiments. Skin friction magnitude error was observed to evolve relatively consistently radially, while vector direction error showed increased sensitivity to local perturbations in surface temperature.

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