# Unsteady Dynamics of Impinging Jet with Swirl and Premixed Combustion Studied by PIV and PLIF

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Impinging jet-flames have wide applications in industrial and domestic heating purposes, in particular for intensive heating of solid materials. The present work focuses on experimental study of flow structure and coherent structures in impinging jets with strong swirl and combustion by a combined application of OH PLIF, HCHO PLIF and PIV. To reveal coherent structures, the experimental data were processed by proper orthogonal decomposition (POD).

The jet flow was produced by a swirl burner, oriented vertically, and impinged normally on a flat metallic plate. The burner consisted of an axisymmetric contraction nozzle with a vane swirler mounted inside. The inner diameter of the nozzle was d = 15 mm. The swirl rate was 1.0 to induce vortex breakdown. The impinged plate represented bottom of a steel cylindrical tank (with the diameter of 300 mm) installed above the nozzle. We consider two cases of the nozzle-to-plate distances H, namely, 1d and 3d. The equivalence ratio of the propane-air mixture issued from the nozzle was 0.7. The Reynolds number of the jet determined by the bulk velocity of the air flow ($U_0$ = 5 m/s) and the viscosity of air was Re = 5 000. To provide PIV measurements, the air flow was seeded by $TiO_2$ particles with the mean size of approximately 0.5 μm.

The used stereoscopic PIV system included pair of CCD cameras (Bobcat IGV-B2020, 4 Mpix, 8 bit) and double-head pulsed Nd:YAG laser (Beamtech Vlite 200, 532 nm, 7 ns pulse with 200 mJ). The cameras were equipped with lenses (Sigma 50mm DG MACRO) and narrow-band optical filters (532 nm ± 5 nm). The OH PLIF system consisted of a tunable pulsed dye laser (Sirah), pumped by a pulsed Nd:YAG laser (QuantaRay), and UV-sensitive ICCD camera (Princeton instruments PI-MAX-4, 16 bit), equipped with a UV-lens and band-pass optical filter. The average pulse energy of the tunable laser, excited $Q_1(8)$ line of the $A^2\Sigma–X^2\Pi$ (1–0) band, was approximately 5 mJ. The HCHO PLIF system consisted of a pulsed Nd:YAG laser Quantel Brilliant B (355 nm, 8 ns pulse with 50 mJ), UV-sensitive image intensifier (LaVision IRO) and sCMOS camera (LaVision, Imager sCMOS, 5 Mpix, 16 bit). Laser sheets thickness in the measurement plane (in the central cross-section of the jet) was below 0.8 mm.

The performed combined study of coherent flow structures by PIV and flame front deformations by OH and HCHO PLIF in impinging swirling jets with premixed combustion has revealed two kinds of large-scale organized flow structures. One kind corresponds to vortex structures forming along the conical jet and causing regular deformations of the flame front. Another corresponds to large-scale flow oscillations during jet impingement onto the surface, statistically correlated with HCHO intensity inside the central recirculation zone.

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