Numerical and experimental investigation of lean turbulent premixed flames in a rectangular duct-type combustor

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Abstract

This paper reports the results and progress of simultaneous PIV and chemiluminescence visualization experiments with LES simulations for stabilized lean turbulent premixed flames behind a backward-facing step under representative equivalence ratio and initial temperature variations. The experimental rectangular duct-type burner was designed with quartz glass to facilitate 2D image acquisition and minimize interference of wall heat loss. An Artificially Thickened Flame (ATF) model based on OpenFOAM v6's rhoReactingBuoyantFoam was applied to perform large-vortex simulations of the turbulent premixed flames under the representative initial conditions.

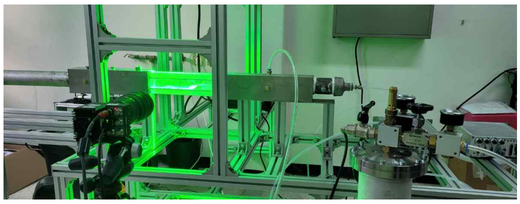

Figure 1: Left: Calculational domain with mesh grid and boundary conditions. Right: Experimental setup of a backward-facing step combustor.

Table 1: Initial conditions for C_3H_8/air mixtures in LES simulations, data saving starts after 10 cycle times to stabilize the flame and finishes when 200 data sets are acquired at time intervals.

T_0 [K]	Re	Φ	U_{in} [m/s]	$S_{L,0}$ [cm/s]	t_{cycle} [s] $(= L_x/U_{in})$	t_{start} [s]	t_{stop} [s]	Δt [s]
300	5000	0.65	3.678	20.549	0.070688	0.72	1.44	0.00360
400	6000	0.60	7.183	29.068	0.036195	0.37	0.74	0.00185
500	7000	0.55	12.266	39.369	0.021197	0.21	0.42	0.00105

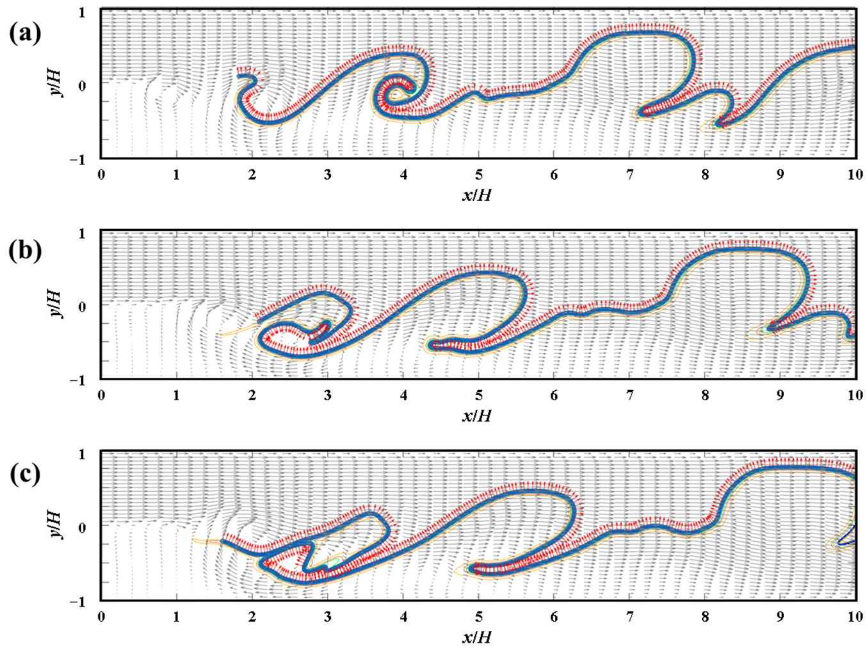

Figure 2: Iso-contour lines of the heat release rate (1/100Max(HRR) is yellow line, 1/20 Max(HRR) is orange line, 1/10Max(HRR) is green line), normal vectors (red arrow) for the flame front (c = 0.9 is blue line) and velocity vectors of the flow field captured instantaneously at (a) t_1, (b) $t_1 + \Delta t$, and (c) t_1+2Δt for (T_0, Re, Φ) = (400 K, 6000, 0.60).

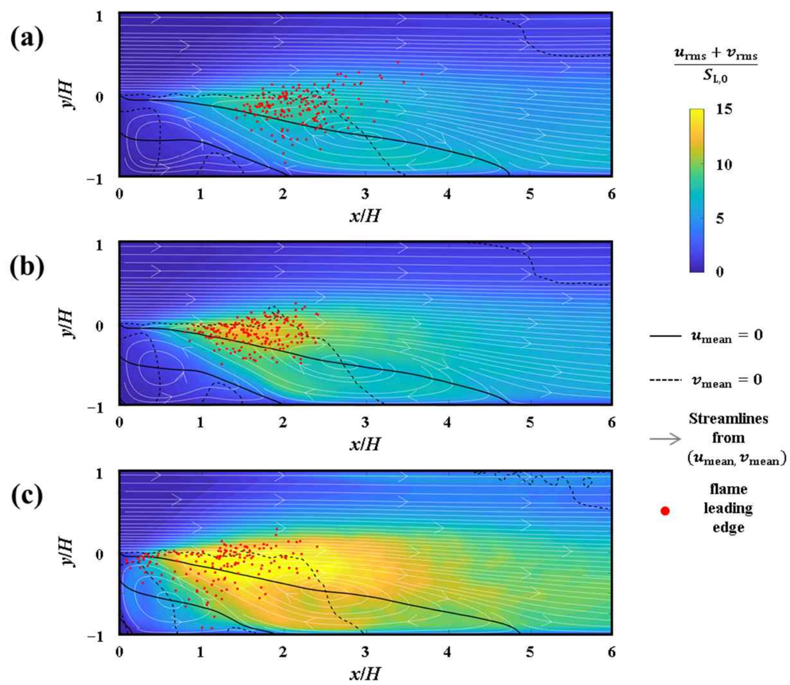

Figure 3: Streamlines and zero-velocity contours for the mean flow velocity, and each position of the flame leading edge superimposed on turbulence intensity: (T_0, Re, Φ) = (a) (300 K, 5000, 0.65), (b) (400 K, 6000, 0.60), and (c) (500 K, 7000, 0.55).

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