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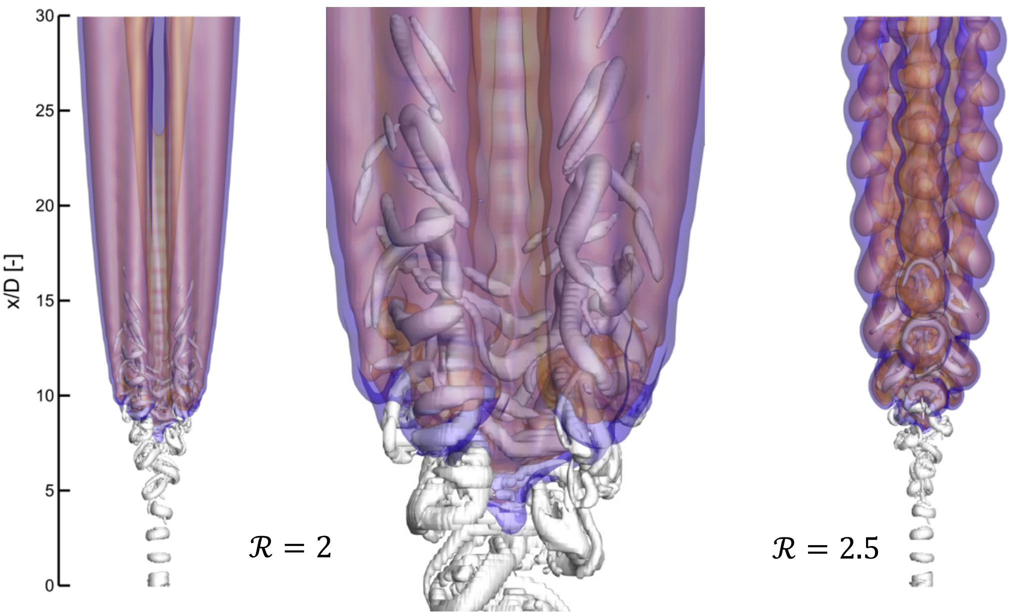
Active flame control by mass flow oscillations and shear layer disturbance

Wawrzak K[1], Wawrzak A[1], Tyliszczak A[1]*
*lead presenter: artur.tyliszczak@pcz.pl
1 Czestochowa University of Technology, al. Armii Krajowej 21, 42-201 Czestochowa, Poland

Jet-type flames have been previously shown to be effectively controlled by low-energy modulated excitation [1]. In this work, we apply a specially designed excitation combining the axial and radial velocity components, $u_a(t) = A_a\, sin(2\pi f_a t)$ and $u_r(t) = A_r\, cos(\theta - 2\pi f_r t)\; g(r)$, where t denotes time and θ represents the azimuthal coordinate. The symbols A_a, A_r are the excitation amplitudes, f_a, f_r stand for the excitation frequencies and $g(r)$ is the masking function. Provided that A_a and A_r exceed the amplitude of natural turbulent fluctuations, a key parameter determining the flow dynamics is the ratio of the excitation frequencies, $\mathcal{R} = f_a/f_r$. When $\mathcal{R} = 2$, the main jet stream splits into two branches resembling the flame bifurcation. When $2 < \mathcal{R} < 3$, the jet divides into separate branches or takes a form of double helix. So far, this type of spectacular splitting has been shown to occur only for constant-density jets. In this study, we consider nitrogen-diluted hydrogen flame in a hot co-flow at a low Reynolds number, $Re \approx 1500$. The research is performed by applying a high-order in-house LES solver combined with the laminar chemistry approach for combustion modelling. We show that multi-armed splitting can be induced in a flame, as shown in Fig. 1, and analyze how the applied excitation changes the flame characteristics (temperature peak, fuel consumption rate, stability, etc.). The obtained results show that the oxidizer engulfing the separated arms induces large-scale mixing, resulting in a flame volume that is 2–4 times larger than in unexcited cases, and characterizes enhanced temporal stability. Radial profiles of the axial velocity and mixture fraction become more uniform and exhibit stronger off-axis mixing. This leads to a more uniform radial temperature distribution, as well as a rapid axial increase and subsequent stabilization of the spatially averaged temperature.



References

[1] Tyliszczak, A. and Wawrzak, A. A numerical study of a lifted H_2/N_2 flame excited by an axial and flapping forcing. Scientific Reports. 2022; 12(1):2753.