JET-FLAME COMBUSTION. DIAGNOSTICS OF HYDRODYNAMIC INSTABILITY MODES AND FLOW CONTROL

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Abstract: The paper reports on the results of experimental study of jet flames by particle image velocimetry technique. The focus is placed on the analysis of the most intensive hydrodynamics instability modes, identification of their role in flame stabilization mechanism, and on possibility to optimize the combustion by affecting the hydrodynamics modes. Velocity field decomposition techniques were used to extract coherent velocity fluctuations. For swirling jet flames, it was found that the vortex core took shape of a spiral due to the axial flow deceleration caused by expansion of the jet flow. For high enough swirl rates, the axial velocity decreased down to negative values, corresponded to a central recirculation zone. For these high-swirl jets, a global instability mode dominated dynamics of the flow downstream the burner. The mode correspondedto a coherent structure, consisted of a pair spiral vortices, viz. a precessing vortex core and secondary helical vortex. The coherent structure was also present after ignition of the flame. The secondary helical vortex provided mixing of the fuel-rich jet with the ambient air and allowed stabilization of the flame base near the burner. It is shown that mixing and combustion can be intensified by affecting instability modes of the flow via imposing proper oscillations to the jet flow rate.

Keywords: jet-flame; coherent structures; large-scale vortices; flow control; efficient fuel combustion

References

1. Gupta, A. K., D. G. Lilley, and N. Syred. 1984. *Swirl flows*. Kent, U.K.: Abacus Press. 475 p.
2. Lefebvre, A. H., and D. R. Ballal. 2010. *Gas turbine combustion: Alternative fuels and emissions*. 3rd ed. CRC Press. 538 p.
3. Zel'dovich, Ya. B., P. Ya. Sadovnikov, and D. A. Frank-Kamenetskiy. 1947. Okislenie azota pri gorenii [Oxidation of nitrogen during combustion]. Moscow–Leningrad: Izd-vo AN SSSR. 147 p.
4. Gad-el-Hak, M. 2000. *Flow control: Passive, active, and reactive flow management*. Cambridge University Press. 421 p.
5. Holmes, P., J. L. Lumley, and G. Berkooz. 1996. *Turbulence, coherent structures, dynamical systems and symmetry*. Cambridge University Press. 384 p.
6. Ginevsky, A. S., Y. V. Vlasov, and R. K. Karavosov. 2004. *Acoustic control of turbulent jets*. Springer. 235 p.

7. Broze, G., and F. Hussain. 1996. Transitions to chaos in a forced jet: Intermittency, tangent bifurcations, and hysteresis. *J. Fluid Mech.* 311:37–71.
8. Baillot, F., and D. Demare. 2007. Responses of a lifted non-premixed flame to acoustic forcing. Part 2. *Combust. Sci. Technol.* 179:905–932.
9. Syred, N., and J. Beer. 1972. The damping of precessing vortex cores by combustion in swirl generators. *Astronaut. Acta* 17:783–801.
10. Syred, N. 2006. A review of oscillation mechanisms and the role of the precessing vortex core (PVC) in swirl combustion systems. *Prog. Energ. Combust. Sci.* 32:93–161.
11. Cala, C. E., E. C. Fernandes, M. V. Heitor, and S. I. Shtork. 2006. Coherent structures in unsteady swirling jet flow. *Exp. Fluids* 40:267–276.
12. Stohr, M., R. Sadanandan, and W. Meier. 2011. Phase-resolved characterization of vortex–flame interaction in a turbulent swirl flame. *Exp. Fluids* 51:1153–1167.
13. Markovich, D. M., S. S. Abdurakipov, L. M. Chikishev, V. M. Dulin, and K. Hanjalic. 2014. Comparative analysis of low- and high-swirl confined flames and jets by proper orthogonal and dynamic mode decompositions. *Phys. Fluids* 26:065109.

Received December 18, 2015

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