# ON COMBUSTION REGIMES IN SWIRLING JETS IMPINGING ON A FLAT SURFACE

D. K. Sharaborin[1,2], R. V. Tolstoguzov[1,2], V. M. Dulin[1,2], and D. M. Markovich[1,2]

[1]Kutateladze Institute of Thermophysics, Siberian Branch of the Russian Academy of Sciences, 1 Lavrentiev Av., Novosibirsk 630090, Russian Federation
[2]Novosibirsk State University, 2 Pirogova Str., Novosibirsk 630090, Russian Federation

**Abstract:** The paper reports the results of experimental study of the flow structure and flame shape during combustion of a propane/air mixture in swirling jets impinging on a cold metallic surface. The equivalence ratio was 0.7 and the Reynolds number of the jet was 5,000. Using planar optical methods PIV (particle image velocimetry) and HCHO PLIF (planar laser-induced fluorescence), the velocity distributions and flame front location in the axial cross section of the flows were measured. For the distances between the nozzle and surface of three nozzle diameters, a significant increase of the fluorescence intensity in the near-wall region for formaldehyde and other organic compounds when excited at a wavelength of 355 nm was detected. This effect appears to be due to the cooling of the combustion products during heat exchange with the metallic surface, temperature decrease inside the central recirculation zone, and reduction of the combustion efficiency.

**Keywords:** swirling jet; turbulent swirling flame; laser diagnostics; near-wall combustion

**DOI:** 10.30826/CE19120208

## Acknowledgments

The work was supported by the Russian Science Foundation (grant No. 16-19-10566).

## References

1. Syred, N., and J. M. Beer. 1974. Combustion in swirling flows: A review. *Combust. Flame* 23(2):143–201.
2. Gupta, A. K., D. G. Lilley, and N. Syred. 1984. *Swirl flows*. Kent, U.K.: Abacus Press. 475 p.
3. Weber, R., and J. Dugué. 1992. Combustion accelerated swirling flows in high confinements. *Prog. Energ. Combust.* 18(4):349–367.
4. Luo, D. D., H. S. Zhen, C. W. Leung, and C. S. Cheung. 2010. Premixed flame impingement heat transfer with induced swirl. *Int. J. Heat Mass Tran.* 53(19-20):4333–4336.
5. Singh, G., S. Chander, and A. Ray. 2012. Heat transfer characteristics of natural gas/air swirling flame impinging on a flat surface. *Exp. Therm. Fluid Sci.* 41:165–176.
6. Chander, S., and G. Singh. 2013. Effect of helical vane swirler geometry on heat transfer characteristics for compressed natural gas/air swirling flame impinging on a flat surface. *ASME 2013 Mechanical Engineering Congress and Exposition (International)*. San Diego, CA: American Society of Mechanical Engineers. V08AT09A018.
7. Singh, G., and S. Chander. 2013. Effect of swirl intensity on heat transfer characteristics of swirling flame impinging on a flat surface. *ASME 2013 Mechanical Engineering Congress and Exposition (International)*. San Diego, CA: American Society of Mechanical Engineers. V08AT09A021.
8. Singh, S., and S. Chander. 2014. Heat transfer characteristics of dual flame with outer swirling and inner non-swirling flame impinging on a flat surface. *Int. J. Heat Mass Tran.* 77:995–1007.
9. Dreizler, A., and B. Böhm. 2015. Advanced laser diagnostics for an improved understanding of premixed flame–wall interactions. *P. Combust. Inst.* 35(1):37–64.
10. Edwards, C. F., N. R. Fornaciari, C. M. Dunsky, K. D. Marx, and W. T. Ashurst. 1993. Spatial structure of a confined swirling flow using planar elastic scatter imaging and laser Doppler velocimetry. *Fuel* 72:1151–1159.
11. Cheng, R. K. 1995. Velocity and scalar characteristics of premixed turbulent flames stabilized by weak swirl. *Combust. Flame* 101:1–14.
12. Stella, A., G. Guj, J. Kompenhans, M. Raffel, and H. Richard. 2001. Application of particle image velocimetry to combusting flows: Design considerations and uncertainty assessment. *Exp. Fluids* 30:167–180.
13. Johnson, M. R., D. Littlejohn, W. A. Nazeer, K. O. Smith, and R. K. Cheng. 2005. A comparison of the flowfields and emissions of high-swirl injectors and low-swirl injectors for lean premixed gas turbines. *P. Combust. Inst.* 30:2867–2874.
14. Cheng, R. K., D. Littlejohn, W.. A. Nazeer, and K. Smith. 2008. Laboratory studies of the flow field characteristics of low-swirl injectors for adaptation to fuel-flexible turbines. *J. Eng. Gas Turb. Power* 130:021501.
15. Korobeinichev, O. P., A. G. Shmakov, A. A. Chernov, D. M. Markovich, V. M. Dulin, and D. K. Sharaborin.

2014. Spatial and temporal resolution of the particle image velocimetry technique in flame speed measurements. *Combust. Explo. Shock Waves* 50(5):510–517.

16. Kohse-Höinghaus, K. 1994. Laser techniques for the quantitative detection of reactive intermediates in combustion systems. *Prog. Energ. Combust.* 20:203–279.
17. Hassel, E. P., and S. Linow. 2000. Laser diagnostics for studies of turbulent combustion. *Meas. Sci. Technol.* 11:R37–R57.
18. Miles, R. B., W. R. Lempert, and J. N. Forkey. 2001. Laser Rayleigh scattering. *Meas. Sci. Technol.* 12:R33–R51.
19. Glassman, I. 1996. *Combustion*. 3rd ed. San Diego, CA: Academic Press. 631 p.

*Received January 18, 2019*

## Contributors

**Sharaborin Dmitriy K.** (b. 1989) — junior research scientist, Kutateladze Institute of Thermophysics, Siberian Branch of the Russian Academy of Sciences, 1 Acad. Lavrentieva Av., Novosibirsk 630090, Russian Federation; junior researcher, Novosibirsk State University, 2 Pirogova Str., Novosibirsk 630090, Russian Federation; Sharaborin.d@gmail.com

**Tolstoguzov Roman V.** (b. 1994) — research engineer, Kutateladze Institute of Thermophysics, Siberian Branch of the Russian Academy of Sciences, 1 Acad. Lavrentieva Av., Novosibirsk 630090, Russian Federation; Ph.D. student, Novosibirsk State University, 2 Pirogova Str., Novosibirsk 630090, Russian Federation; enot.roman@gmail.com

**Dulin Vladimir M.** (b. 1983) — Doctor of Science in physics and mathematics, head of laboratory, Kutateladze Institute of Thermophysics, Siberian Branch of the Russian Academy of Sciences, 1 Acad. Lavrentieva Av., Novosibirsk 630090, Russian Federation; senior teacher, Novosibirsk State University, 2 Pirogova Str., Novosibirsk 630090, Russian Federation; vmd@itp.nsc.ru

**Markovich Dmitriy M.** (b. 1962) — Corresponding Member of the Russian Academy of Sciences, professor, director, Kutateladze Institute of Thermophysics, Siberian Branch of the Russian Academy of Sciences, 1 Acad. Lavrentieva Av., Novosibirsk 630090, Russian Federation; deputy head of laboratory, Novosibirsk State University, 2 Pirogova Str., Novosibirsk 630090, Russian Federation; dmark@itp.nsc.ru