MICROSCALE COMBUSTION DYNAMICS: INVESTIGATING INSTABILITY TRANSITIONS IN HEATED CHANNELS

D.S. ASTAKHOV[1], *I.A. YAKOVLEV*[1]

[1]*Tomsk Scientific Center of the Siberian Branch of the Russian Academy of Sciences, 10/4, Akademicheskii prospect, 634055, Tomsk, Russia*

Recently, energy microgenerators have been developed as an alternative to chemical batteries [1]. These generators offer several advantages, including lower mass, high energy density, and fast charging. The main component of such devices is the combustion chamber. However, due to the small ratio of heat release volume to heat loss surface, their efficiency is low and their operating conditions are limited. Effective designs for improving microscale combustion involve systems that have thermal interaction with adjacent walls or porous materials, which provide excess enthalpy combustion or heat recuperation.

Microscale burners exhibit combustion instability when approaching flammability limits. To investigate this phenomenon, it is convenient to explore a simplified system such as a narrow channel with controlled wall temperature profile. Maruta et al. [2] identified three characteristic combustion regimes in straight channels, depending on the inlet flow velocity. Starting from a normal steady flame, a gradual decrease in flow velocity leads to formation of flames with repetitive extinction and ignition (FREI), which stabilizes again as a weak flame at extremely low flow velocities.

This numerical study is devoted to formation of such unstable regime during combustion of a lean methane-air mixture (φ = 0.6) in four planar channels of different widths (h, from 0.85 to 2 mm) with focus on the instability transition. The problem statement was two-dimensional and included very gradual temperature profile at the wall to accurately capture the transitional effect. Details of the mathematical model could be found in [3]. To analyze the instability during the transition between combustion modes, the results were presented in the form of a diagram of the maximum heat of reaction as a function of the input velocity. For instance, the bifurcation map for h = 1.5 mm is shown in Fig. 1.

The diagram shows the transitional pulsating mode, which differs from FREI due to incomplete flame quenching. The study found that the range of velocities in which the transient mode occurs, as well as the character of the pulsations, depend on the channel width. However, the study also found conditions under which the pulsating mode cannot be explicitly determined due to gradual increasing of the pulsating amplitude until the fully-developed extinction/ignition mode (h = 0.85 mm). The study also found that the transition between modes is always subcritical and that the hysteresis phenomenon is observed in all cases neat the bifurcation point. In channels less than 2 mm wide, a combined mode was observed in the form of alternation between pulsating and extinction/ignition cycles.

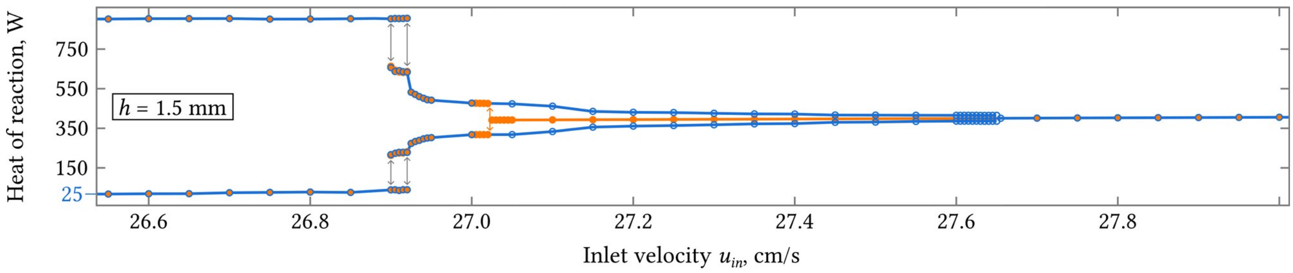

Fig. 1. Bifurcation diagram showing the maximum heat of reaction in the channel, depending on the inlet velocity u_{in} for the channel diameter of h = 1.5 mm

REFERENCES

[1] L. Cai, J. E, J. Li, J. Ding, and B. Luo, “A comprehensive review on combustion stabilization technologies of micro/meso-scale combustors for micro thermophotovoltaic systems: Thermal, emission, and energy conversion,” *Fuel*, vol. 335, p. 126660, Mar. 2023, doi: 10.1016/j.fuel.2022.126660.

[2] K. Maruta, T. Kataoka, N. I. Kim, S. Minaev, and R. Fursenko, “Characteristics of combustion in a narrow channel with a temperature gradient,” Proceedings of the Combustion Institute, vol. 30, no. 2, pp. 2429–2436, Jan. 2005, doi: 10.1016/j.proci.2004.08.245.

[3] I. Yakovlev, D. Astakhov, S. Zambalov, R. Fursenko, J. Li, and A. Maznoy, “Transition to unstable oscillatory flames in porous media combustion,” *Combustion and Flame*, vol. 252, p. 112752, Jun. 2023, doi: 10.1016/j.combustflame.2023.112752.