Visualization of Conventional and Combusting Subsonic Jet Instabilities

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Abstract

Based on new information obtained for free microjets, this study is aimed to explain some phenomena of flame evolution at round and plane propane and hydrogen microjet combustion at presence of transverse acoustic field. It gives an overview of recent experimental results on instability and dynamics of jets at low Reynolds numbers and provides the recent advances in jet flow stability and combustion. Some clarification of the differences between top-hat and parabolic round and plane jet instability will also be given (Kozlov et al. 2016, Kozlov et al. 2016, Kozlov et al. 2016, Shmakov et al. 2017).

Influence of initial conditions at the nozzle exit on the characteristics of the round and plane microjet evolution

A round macrojet with top-hat mean velocity profile at the nozzle exit is prone to the Kelvin–Helmholtz instability in the form of ring vortices, whereas the round macrojet with parabolic mean velocity profile at the nozzle exit results in an extended laminar flow region and suppression of the vortices (see figure 1).

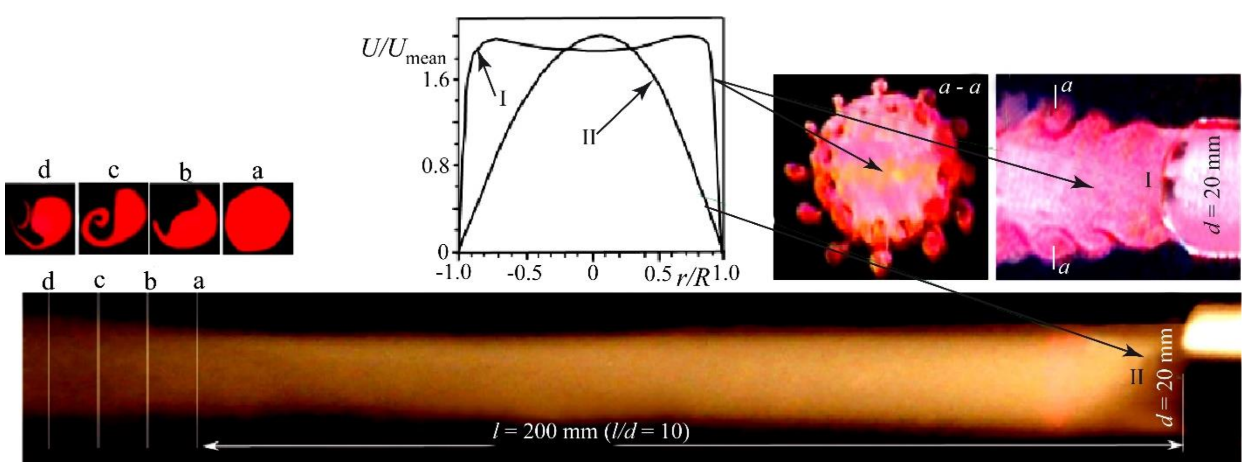

Figure 1: Influence of initial conditions at the nozzle exit on structure and characteristics of a round jet evolution: I, II - top-hat and parabolic mean velocity profiles, accordingly; a, b, c, d - macrojet cross sections, U_0= 5 m/sec ($Re = U_0 \times d / \nu$ = 6667).

Plane macrojet with top-hat and parabolic mean velocity profile at the nozzle exit is prone to sinusoidal instability (see figure 2). The round macrojet with parabolic mean velocity profile at the nozzle exit results in an extended laminar flow region and suppression of the ring vortices.

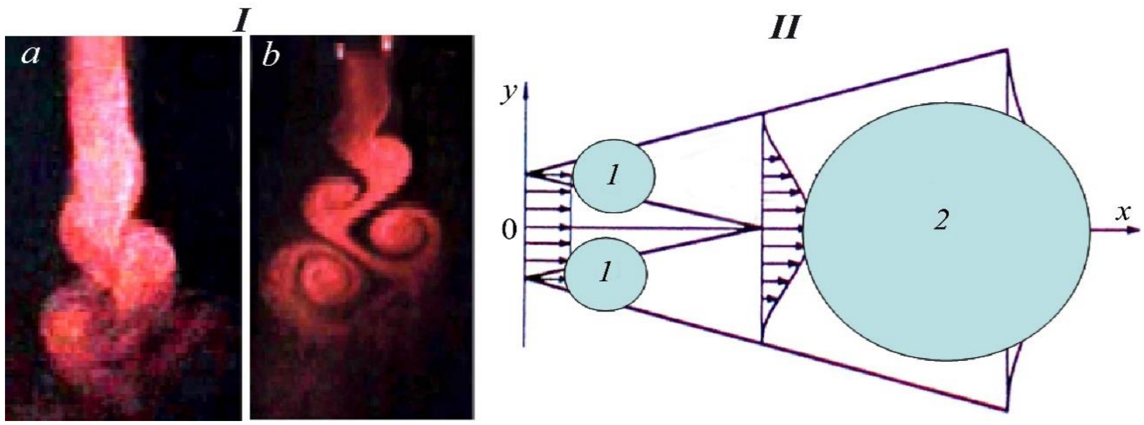

Figure 2: Sinusoidal instability of the plane macrojet with top-hat and parabolic mean velocity profile at the nozzle exit – *I* (*a* – under natural conditions, *b* - under external acoustic forcing at frequency *f* = 40 Hz). Plane macrojet with top – hat mean velocity profile at the nozzle exit involve three independent of each other instability regions: 1 - two independent of each other narrow regions of strong velocity gradient near nozzle, 2 - region with parabolic mean velocity profile far downstream from a nozzle – *II*.

Influence of acoustics on the characteristics of the round and plane microjet evolution (see figure 3).

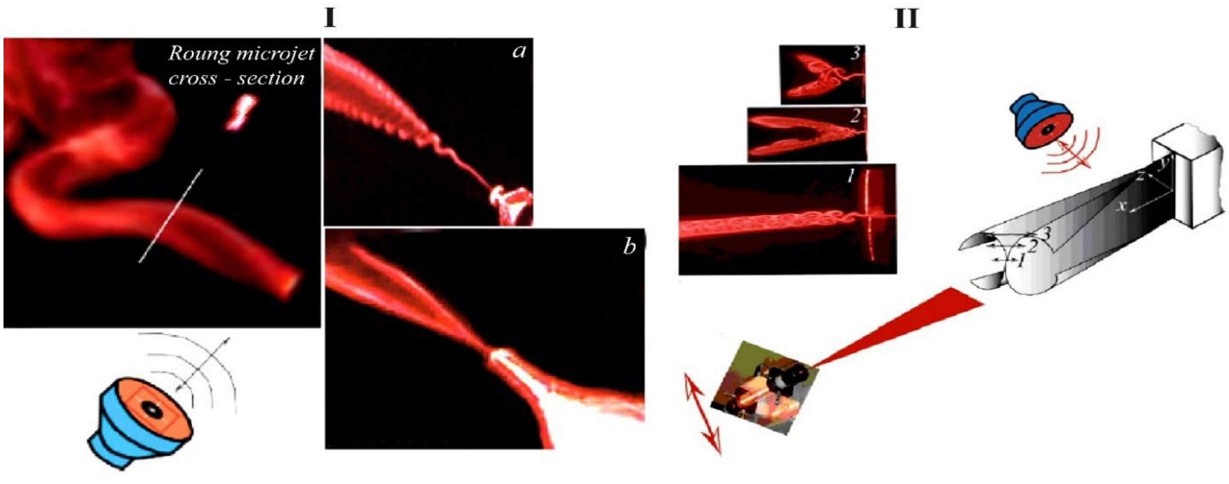

Figure 3: Round microjet flattening (*f* = 40 Hz) and bifurcation (*a* - *f* = 200 Hz, *b* – 1500 Hz) in a transverse acoustic field (nozzle diameter *d* = 200 mm) – *I*. Bifurcation scheme of the plane macrojet in a transverse acoustic field (nozzle: *l* = 36 mm, *h* = 200 mm): flow patterns in *x*-*z* planes at variation of the *y* coordinate (1, 2, and 3 correspond to y = 0, 15, and 18 mm, respectively), *f* = 150 Hz, 90 dB – *II*.

Diffusion combustion of the round and plane propane and hydrogen microjet in a transverse acoustic field (see figure 4, 5).

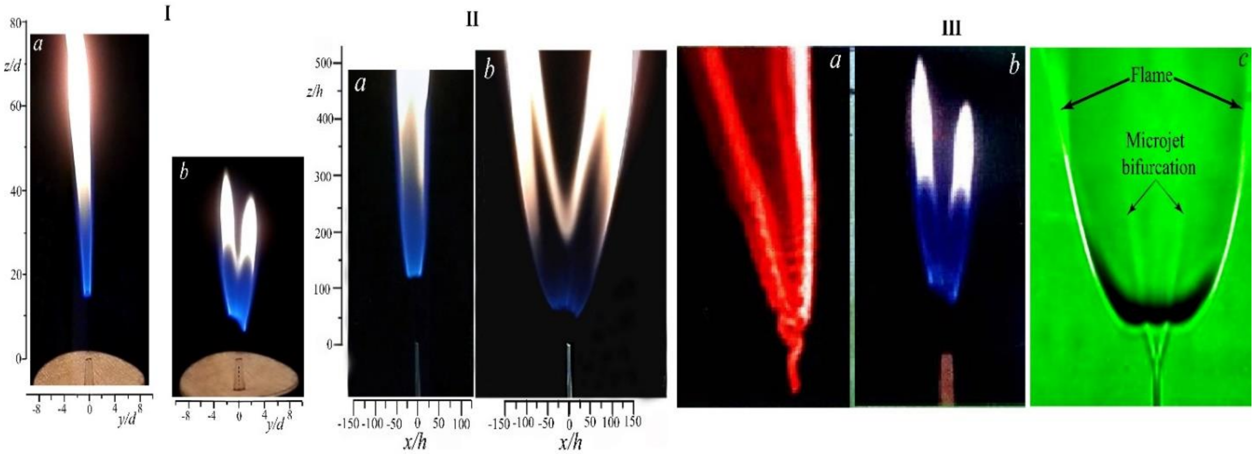

Figure 4: Round (I) and plane (II) microjet flame bifurcation in a transverse acoustic field: nozzle No. 1, d = 0.5 mm, acoustics, f = 5 - 7.5 kHz, U_0 = 12.5 m/sec (I); nozzle No. 2, l = 2 mm, h = 200 micm, acoustics, f = 1 – 3 kHz, U_0 = 21 m/sec (II); without acoustics (*a*), with acoustics (*b*), A = 90 dB. III - Round microjet bifurcation (*a*), round propane microjet flame bifurcation (*b*), and shadowgraph image of a round propane microjet combustion (*c*).

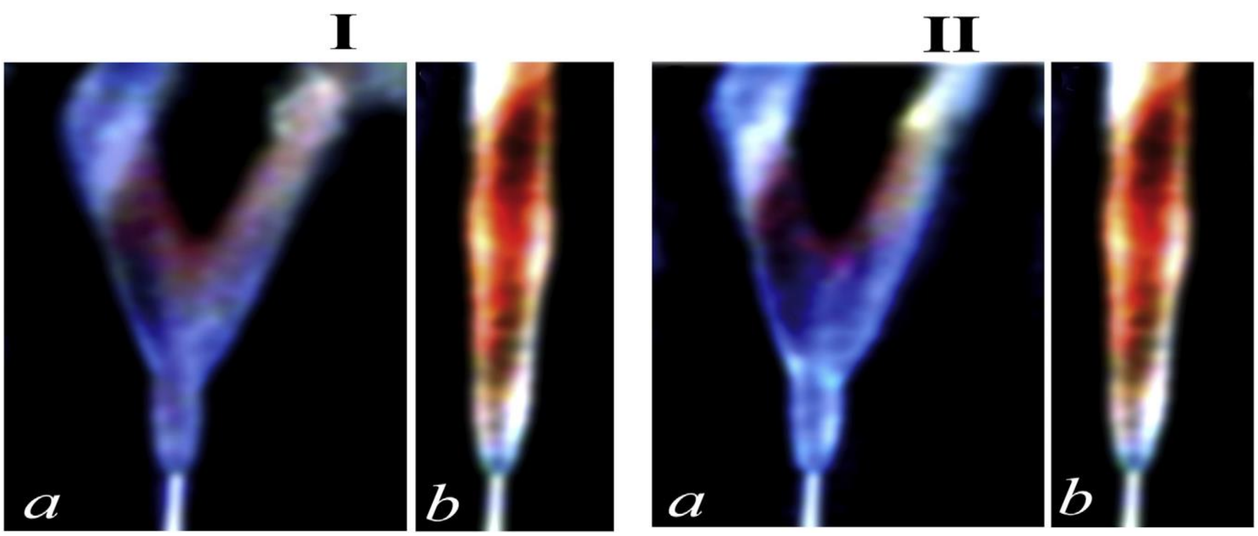

Figure 5: Bifurcation patterns of the attached flame during combustion of the round hydrogen microjet in transverse acoustic field ($U_{microjet}$ = m/sec): I, II e 38(a) and 51(b); a e with acoustic forcing (f = 7 - 15 kHz, A = 110 dB), b e without acoustic excitation, nozzle diameter is d ¼ 1 mm.

Conclusion

Visualizations of conventional and combusting subsonic jet instabilities are presented. Features of structure and characteristics of subsonic round and plane macro- and microjets evolution depending on initial conditions at the nozzle exit and acoustic effect are shown. It is found, that round and plane propane and hydrogen microjets combustion in a transverse acoustic field result in flame bifurcation.

Acknowledgements

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