REVERSE OF LAMINAR-TURBULENT TRANSITION IN A SUPERSONIC UNDEREXPANDED MICROJETS

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Abstract The results of measurements of supersonic length of underexpanded microjets outflowing into the atmosphere, by Pitot tube and the millimeter-diameter jets outflowing into low pressure chamber on the laminar and turbulent regimes are presented. Measurements of the supersonic length were supplemented with measurements of the mass flow rate pulsations on the jet axis by hot-wire anemometer and schlieren-visualization of the flow field. Experiments were conducted under the equal/approximately equal Reynolds number of micro - and millijets. It was found the restoration of laminar flow in jets at a certain values of the jet underexpansion (Reynolds number of the jet).

The experimental study of the structure and fluctuations of mass flow rate in nitrogen and air supersonic underexpanded jets outflowing from the round sound nozzles is carried out. Studies have been performed in the range of jet underexpansion n ($n = NPR \Big/ \left(\frac{\gamma+1}{2}\right)^{\frac{\gamma}{\gamma-1}}$) from 1 to 30 using the Pitot tube and the CCA-hot-wire anemometer. First discovered the effect of relaminarization turbulent jet which leads to recovery of the relative length of the supersonic core of underexpanded jet L_s/D after its decline as a result of the laminar-turbulent transition. The experiments were performed for both microjets outflowing into the atmosphere from the nozzle diameter D = 340 ÷ 10 microns [1-3] and for jet outflowing from the nozzle diameter of 1 mm into low pressure area. The experiments were performed in such a way that the Reynolds number Re_D, calculated from the diameter of the nozzle D and the output flow parameters, is the same for millimeter nozzle and micronozzles. At a fixed value of the stagnation temperature value Re_D linearly related to the value n.

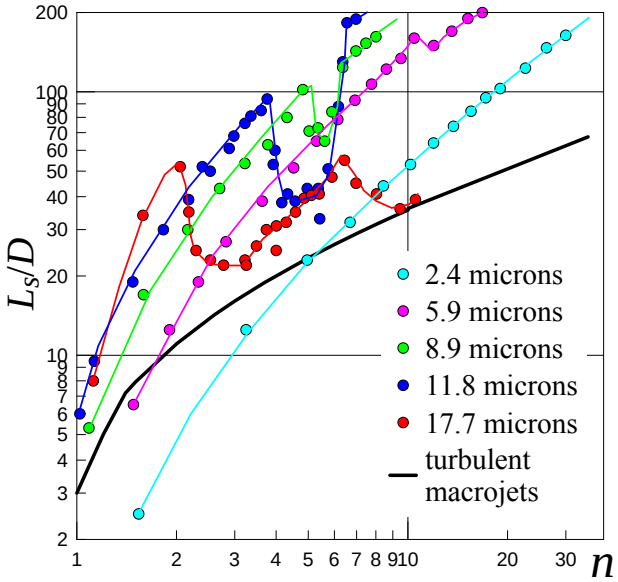

Figure 1. Dependence of the length of jet supersonic core on the value of underexpansion for several effective nozzle diameters.

It has been shown quite good quantitative agreement dependencies of L_s/D on n for jets from micro and millimeter nozzles. Figure 1 shows the results of measuring the length of a supersonic core of jet for nozzle diameter of 1 mm, Reynolds number of which coincides with Re_D for indicated in the graph diameter effective micronozzles. In figure 1 one can see the initial growth of the L_s/D in the laminar flow regime, the drop value of L_s/D as a result of the

laminar-turbulent transition in the jet and recovery of L_s/D with further increase jet underexpansion n. Transition flow regime in the jet from laminar to turbulent and back confirmed by measurements distribution of mass flow rate pulsations along jet axis.

Schlieren-visualization of the flow field in figure 2 clearly shows the effect of reversing the laminar-turbulent transition in the jet from the nozzle diameter of 35 microns. Initially laminar microjet (1) is turbulized with an increase of underexpansion and the length of the laminar field is reduced (2), (3). With further increase in the value of jet underexpansion the laminar length again begins to increase (4) and subsequently microjet becomes fully laminar (5), and the length of supersonic core L_s/D is restored.

The observed effect of reverse of the laminar-turbulent transition will create dense arrays of supersonic microjets effectively influencing on streams in a different microdevices and processes (cooling surfaces, flow control, suppression of flow pulsations and etc.).

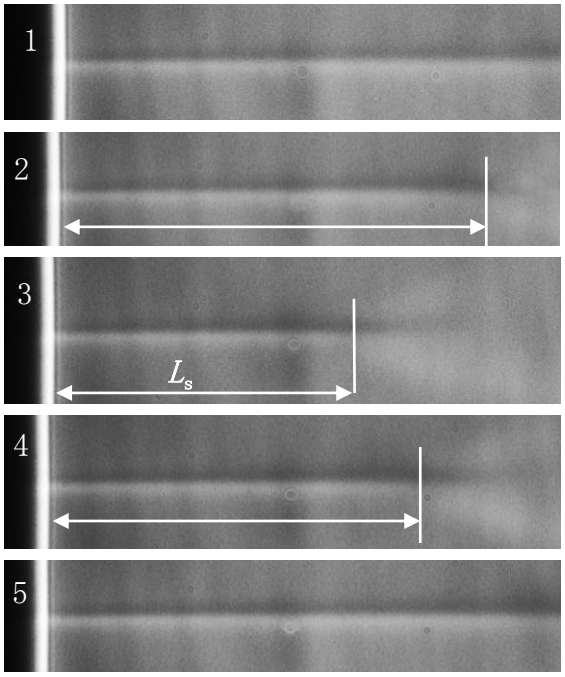

Figure 1. Schlieren-visualization of the flow field of microjet outflowing from the nozzle diameter of 35 microns.

References

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