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EXPERIMENTAL RESEARCH OF THE STRUCTURE OF SUPERSONIC UNDEREXPANDED FLAT AIR MICROJETS

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KEY WORDS

Micronozzles, microjets, supersonic core length

ABSTRACT

In view of the broad possibilities of application of microscopic gas and liquid devices (microfluidics), considerable research interest is presently devoted to studying fluid flows on the microscopic scale, including both the fluid flow in channels and jet emission from micron-sized orifices. Depending on the output pressure, a jet can be either subsonic or supersonic. Both subsonic and supersonic microjets used in macroscopic flow control, noise reduction, and jet cooling systems.
The number of reported experimental investigations devoted to supersonic microjets is not large [1–5]. Previously, we have studied in detail the structure of axisymmetric supersonic microjets [3, 4]. It was found that the relative shock cell size in micro- and macro-jets have no significant differences. However, at some values of the jet pressure ratio, the supersonic core length of microjets exhibits a significant increase as compared to that of macro-jets. Here, the jet supersonic core length defined as the distance from the nozzle exit to a point on the jet axis where the flow velocity attains the local sound velocity value. A transition from the regime of a large supersonic core length to that characteristic of macro-jets takes place at Reynolds numbers between 1100 and 2100 and related to the transition from laminar to turbulent flow.
There have been numerous experimental and theoretical works devoted to studying the structure, noise, and interaction with obstacles for supersonic rectangular macro-jets [6–8]. However, to the best of our knowledge, no published data are available on the supersonic core length of two-dimensional supersonic macro-jets. Experimental investigations of the structure of supersonic microjets not been reported except for our recent work [5], in which data were only presented for a single Reynolds number.
The present work aimed at determining the main characteristics of supersonic flat underexpanded microjets – supersonic core length using two-dimensional micro-jet arrays manufactured using a technology described in [4]. Each nozzle had a cylindrical pre-chamber with a diameter of 4 mm and a wedge shaped narrowing taper part. In the present work, data are presented for jets escaping from nozzles with height in 83.3 μm and 22.3 μm.
The nozzle dimensions and experimental parameters listed in the table 1. Where h is the nozzle height, w is the nozzle width, n is the jet pressure ratio (defined as the ratio of static pressure at the nozzle exit to pressure in the surrounding space), Re is the Reynolds number calculated for the given nozzle height and gas parameters at the nozzle exit, and Kn is the Knudsen number.

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H, (mkm)	W, (mkm)	W/H	N	Re	Knmax
83.3	3822	45.9	1-1.32	2360-7225	0.00042
22.3	2593.	116	1-4	600-2562	0.0014

Table 1: Nozzle dimensions and flow parameters

The supersonic core length of supersonic flat underexpanded microjets was determined from P'0 distributions along the line of intersection of the nozzle symmetry planes. The results presented in Fig. 6. However, the supersonic core length of the jet escaping from a nozzle with h = 22.3 μm at n < 1.5 is greater (long supersonic core length regime) than the values for other micro-jet. An analogous increase in the jet range observed for supersonic axisymmetric microjets [4]. Indeed, it was found in [4] that the supersonic core length of axisymmetric microjets escaping from nozzles with diameters above 60 μm corresponds to that of axisymmetric macro-jets, while the nozzles with diameters below 60 μm exhibit long supersonic core length.

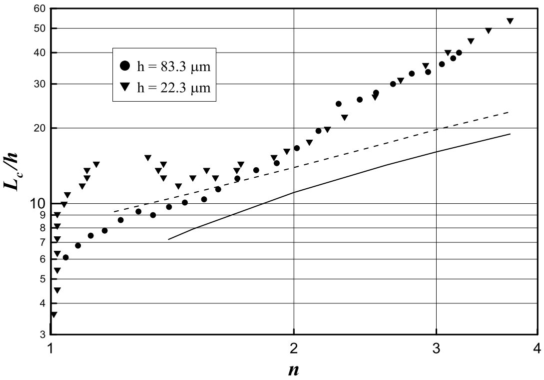

Figure 1: Plot of the supersonic core length of the supersonic microjets escaping from the two-dimensional micro-nozzles.

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