A TURBULENT JET IN A CONCURRENT STREAM
AT A PERMEABLE SURFACE
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The average and pulsation velocity profiles are measured in a rectangular channel during combined pore-slot blowing. Universal functions are proposed which generalize the experimental data obtained in different cross sections and in a wide range of intensities of pore blowing.

In a number of industrial devices (MHD generators, prospective power installations, instruments of plasma-chemical production) the preferred and sometimes the only possible means of controlling the processes of mass and heat exchange in the boundary layer is the combined pore-slot blowing of the working media, when a slot curtain near the wall is organized in addition to the transversely distributed blowing through the permeable wall. The flow realized in such a case can be considered as a semiconfined turbulent jet at a permeable surface in a concurrent stream.

This flow is characterized by a number of specific properties in comparison with purely pore or purely slot blowing. At the same time, combined pore-slot blowing has been studied little in the literature. One can mention only [1, 2], where a boundary jet without a concurrent stream at a permeable surface at low blowing intensities was studied, and [3], which considered a curtain in a burning graphite channel.

The present study was conducted on an apparatus with a working section consisting of a channel of rectangular cross section 31 × 35 mm in size. The tangential boundary jet was formed in a rectangular slot with an exit cross section of 3 × 35 mm. The transverse blowing of gas into the boundary layer was carried out through a plate of porous nickel mounted flush with the lower wall of the channel at a distance of 6 mm from the cut of the slot. The dimensions of the working section of the plate were 235 × 35 mm. The main gas stream arrived at the experimental channel after a section of aerodynamic preparation, as a result of which the longitudinal velocity profile at the entrance to the model was close to rectangular — the relative thickness δ*/δ of displacement was 0.01 and the intensity of longitudinal pulsations at the center of the stream did not exceed 0.015.

All the measurements were conducted with an ATA-1 thermoanemometric instrument. The head was calibrated against a micro-Pitot tube at the middle of the channel at the beginning and end of each series of experiments. The flow-rate parameters for the gas components were recorded from the pressure drop at the measuring disks.

The preliminary qualifying measurements in a boundary jet without blowing in a concurrent stream gave satisfactory agreement with the well-known generalizations for flows of this type [4]. The flow rates of the incoming, slot, and pore gas supplies were varied in the course of the experiments. With a main stream velocity of \( u_{10} = 8 \text{ m/sec} \) three slot blowing velocities were established: \( u_0 = 4, 8, \) and 16 m/sec. With a main stream velocity of \( u_{10} = 20 \text{ m/sec} \) only slot blowing with \( u_0 = 20 \text{ m/sec} \) was examined. For each mode four values of the pore blowing intensity were achieved: \( m = 0.05, 0.03, 0.01, \) and 0. The thermoanemometric measurements were made in five cross sections along the length of the working section with the following dimensionless longitudinal coordinates: \( \bar{x} = x/h = 5.3, 22.0, 38.7, 55.3, \) and 72.0. The distributions of the average and pulsation longitudinal velocities were measured in each cross section.
The experimental results for the cross section \( \bar{x} = 55.3 \) and \( r = 0.5 \) are presented in Fig. 1. The graphs presented permit an estimate of the degree of influence of the pore blowing on the retardation of the jet. It is characteristic that along with considerable deformation of the velocity profiles the usual structure of a semiconfined jet with a maximum longitudinal velocity is retained during intense transverse blowing at considerable distances from the start of the jet (more than \( x = 72 \) at \( m = 0.05 \)). The blowing redistributes the thicknesses of the wall and jet boundary layers, with the total thickness of the jet remaining unchanged under the experimental conditions examined. The latter is connected with the effect of a negative pressure gradient which increases with an increase in the blowing and compensates for the forcing back of the jet by the transverse flow of material.

In the analysis of the velocity profiles presented in Fig. 1 it must be considered that the local velocities \( u \) are normalized with respect to the local velocity of the concurrent flow \( u_1 \) which is not constant along the length of the jet (\( u_1 = 8.0 \) m/sec for mode 1, 8.5 for 2, 9.8 for 3, and 11.4 m/sec for mode 4). Thus, the maximum velocity \( u_m \) under the present conditions in a fixed cross section first decreases, but then increases with the further increase in the blowing intensity and becomes greater than at first. This is explained by the fact that with light blowing the retardation of the jet dominates over its enhancement which is promoted by the supply of mass by the external stream, while with strong blowing the picture is reversed.

The lengths of the initial section of the jet are determined from the dependence of the maximum velocity excess \( u_m - u_1 u_m - u_1 \) on the longitudinal coordinate \( \bar{x} \). It turned out that with an increase in blowing the initial section contracts, almost degenerating at the maximum blowing intensity \( m = 0.05 \) for

**Fig. 1.** Profiles of average (a) and pulsation (b) longitudinal velocities in cross section \( \bar{x} \) = 55.3 at \( r = 0.5 \): 1) \( m = 0 \); 2) 0.01; 3) 0.03; 4) 0.05. \( \sqrt{u^2} \), m/sec.

**Fig. 2.** Generalized dependence for average velocity in middle zone of a boundary jet with \( r = 0.5 \) (a) and with \( r = 1 \) and 2 (b): 1) \( m = 0.01 \); 2) 0.03; 3) 0.05; 4) from Eq. (1).