EFFECT OF OBSTACLES ON FLOW IN A CHANNEL WITH PERMEABLE WALLS

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A study is made of the flow hydrodynamics upon incidence of a jet formed in a permeable channel upon an obstacle located at some distance from the channel output section perpendicular to the jet axis.

In considering jet incidence on the obstacle the entire flow region may be arbitrarily divided into several characteristic regions, the gas dynamics and heat exchange in which depend on a number of conditions: compressibility, turbulence of the exiting jet, presence of a drain flow, etc. One such region is the jet itself, which can be regarded as submerged near the channel exit (at a large distance to the obstacle), while we can distinguish initial and main segments, as well as a segment where the flow deforms under the influence of the transverse obstacle, i.e., the jet changes from free to adhering. The flow in this last region was studied in [1, 2].

From those studies we may conclude that in the Reynolds number range $Re = \overline{u}d/\nu = 2 \cdot 10^4 - 2 \cdot 10^5$, where $\overline{u}$ is the mean velocity over the channel section, d is the nozzle diameter, and ν is the kinematic viscosity coefficient, independent of the initial velocity distribution the effect of the obstacle extends for no more than 1.5 nozzle diameters. Another point common to both studies is that all velocity measurements were performed outside the nozzle from which the jet exited. Data on flow deformation within the nozzle itself at $h_2/d < 1$ are practically unavailable.

The present study is dedicated to investigating the region of interaction between obstacle and jet.

The jet source used was a permeable walled channel having a rectangular cross section. A diagram of the experimental channel is shown in Fig. 1, where 1 is a drain container and 2, a pump. The upper face of the channel was closed — the jet was formed by forcing the medium through the permeable walls.

The transverse obstacle was formed by a plane channel of variable height installed across the jet. Special attention was given to the interaction region for the case in which the effect of the obstacle extends within the source channel, deforming the original velocity and pressure distribution. The measurement method used, stroboscopic visualization of the flow, allowed measurement of velocity fields over practically the entire interaction segment.

Two series of measurements were performed. The first attempted to determine the size of the interaction region and the dependence of this parameter on the height of the drain channel h_2. The height of the permeable channel $h_1 = 10$ mm was maintained fixed in these experiments, while the drain channel height was varied, $h_2 = 7$ and 3.5 mm.

The goal of the second series of measurements was a more detailed study of velocity profiles in the interaction region. In these experiments the permeable channel height was 20 mm, with a drain channel height of 3.2 mm. Other channel dimensions were maintained constant in both series of experiments: width of permeable and drain channels, 60 mm; length of permeable channel, 150 mm; length of supply channel, 200 mm. The working medium used was a 1% solution of hydrochloric acid in distilled water. Its flow rate through the wall was measured using calibrated flow rate washers. The high resistance of the permeable walls (the pressure drop across the wall was almost an order of magnitude greater than the pressure drop along the channel length) insured uniform supply over channel length. The forward wall of the source channel and the surface of the obstacle were both made of polished Plexiglas: The wake pattern of the flow was photographed through the former, while photographs were taken with a pulsed light source through the latter. A line of 0.5-mm-diameter orifices were placed in the

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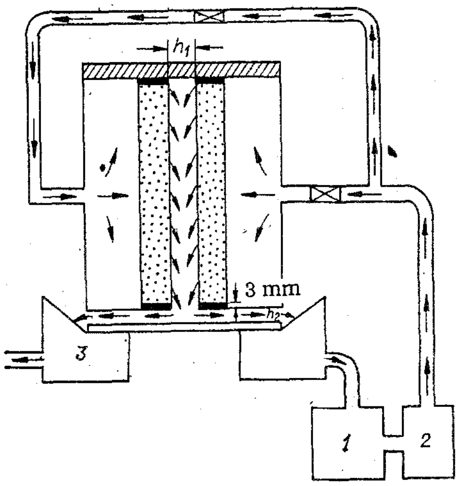

Fig. 1

rear wall of the permeable channel for static pressure measurements. For more detailed pressure measurements a 0.75-mm-diameter tube was inserted through the upper surface of the channel. The end of the tube was sealed and it contained a 0.5-mm orifice 4 mm above the sealed end.

In measuring the velocity distribution by the stroboscopic method hydrogen bubbles formed upon electrolysis of the dissolved acid on the electrodes served as marker particles. The electrodes were formed of 0.05-mm-diameter platinum wire extending along each permeable wall in the direction of the flow. The Reynolds number $Re_w = u_w h_1/\nu$ and $Re = \bar{u}h_1/\nu$, where v_w is the draft velocity on the permeable channel wall and $\bar{u}$ is the mean velocity (over channel section) at the output, comprised 244 and $3.7 \cdot 10^3$ in the first series of experiments, and 580 and $8.5 \cdot 10^3$ in the second.

The static pressure distribution measured in the first series of experiments is shown in Fig. 2, where the solid curve corresponds to a quadratic pressure distribution law, characteristic of an unperturbed flow in a permeable channel [3]:

$$p(0) - p(x) = 1.23\rho(v_{\text{ст}}x/h_1)^2. \tag{1}$$

In Fig. 2, $p = 0.1(p(0) - p(x))$; x is the longitudinal coordinate; x = 0 corresponds to the beginning of the permeable channel; a) $h_1 = 10$ mm, $h_2/h_1 = 0.35$; b) $h_1 = 10$ mm, $h_2/h_1 = 0.7$; c) $h_1 = 20$ mm, $h_2/h_1 = 0.16$; the number 1 marks the obstacle position, points 2 are pressure samples from the wall orifices, and points 3 were measured with the inserted tube. It is evident that for both values of h_2/h_1 the deviation from Eq. (1) which develops under the action of the obstacle begins approximately at $x_1/h_1 \simeq 1$ (where x_1 is the distance from the section to the obstacle).

Velocity distribution measurements are shown in Figs. 3 and 4. In Fig. 3, $h_1 = 20$ mm, $h_2/h_1 = 0.16$; a) $x_1/h_1 = 0.2$; b) $x_1/h_1 = 0.39$; c) $x_1/h_1 = 0.68$; d) $x_1/h_1 = 1.0$. In Fig. 4, $h_1 = 20$ mm; 1) $x_1/h_1 = 1.0$; 2) $x_1/h_1 = 0.68$; $h_1 = 10$ mm; 3) $x_1/h_1 = 1.2$; 4) $x_1/h_1 = 0.68$; u is the axial velocity component, and the subscript 0 indicates values along the channel axis. Figure 4 also shows the function

$$u/u_0 = \cos(\pi/2)[(h_1 - 2y)/h_1] \tag{2}$$

(where y is the distance from the permeable wall), which according to [3] describes the velocity distribution in a channel with permeable walls. It is evident from the data of Figs. 3 and 4 that at $x_1/h_1 \simeq 1.0$ the velocity profile is described well by Eq. (2), i.e., the flow is not perturbed by the boundary. With increase in x_1/h_1 the effect of the transverse wall reduces to a reduction in flow velocity along the axis and its separation into two symmetrical jets.

The fact that independent of the ratio h_2/h_1 the length of the zone of interaction between the obstacle and jet Δx_1, represented in dimensionless form as $\Delta x_1/h_1$, remains practically the same allows the conclusion that in this segment the velocity distribution depends on only one parameter, x_1/h_1. Figure 4 shows velocity profiles for two channel heights (10 and 20 mm) and two values of the parameter $x_1/h_1 \simeq 1$ and 0.68. It is evident that the veloc-

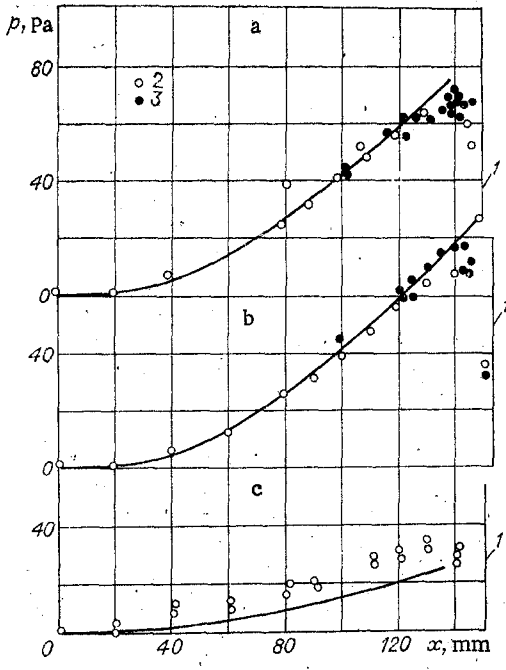

Fig. 2

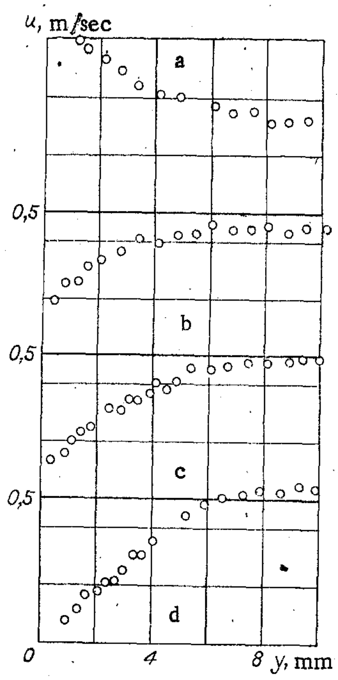

Fig. 3

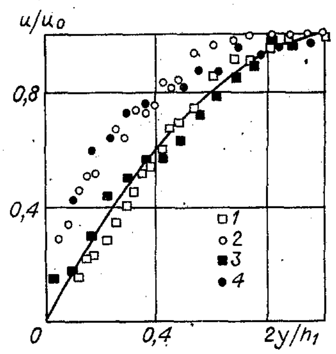

Fig. 4

ity profiles corresponding to the identical value of x_1/h_1 for both channels are close to each other, which indicates the validity of the above conclusion.

We must take note of the static pressure distribution in the channel with height h_1 = 20 mm (see Fig. 2c). In the increasing segment the pressure distribution no longer follows a quadratic law (solid curve). These results were tested by repeated measurements. This result can be explained by the flow becoming non-two-dimensional (for these experiments the ratio of channel width to height h_1 was 3, i.e., half that for the 10-mm-high channel). It is interesting that in this case the velocity distribution in the segment of the flow unperturbed by the obstacle was, as before, nearly cosinusoidal, Eq. (2) (Fig. 4).

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