plate; $V_0$, jet velocity at a hole; $V_5$, jet velocity at distance 5 from the source; $y_2$, dispersion; $N_{Nu}$, Nusselt number; $N_{Re}$, Reynolds number; and $N_{Pr}$, Prandtl number.

LITERATURE CITED


A CIRCULAR TURBULENT JET IN A CROSSFLOW

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An integral method is proposed for calculating a circular turbulent jet propagating in a crossflow. The jet parameters obtained by a numerical method for different values of $Q$ were compared with experimental data. Satisfactory agreement between the sets of data was found.

The interaction and mixing of jets with a crossflow is a complex form of jet flow, and the study of the propagation of such jets is important for planning and designing equipment and devices in which mixing takes place. Several works by foreign and domestic authors have been devoted to the theoretical [1-5] and experimental [6-13] study of the laws of mixing and propagation of turbulent jets in a crossflow. As a rule, the theoretical studies [1-5] are based on integral methods, assume an increase in jet width, and make various other assumptions regarding the conditions of momentum conservation. Most of the investigations have focused on determining the jet axis, and only certain studies have examined laws of change in width, axial velocity, apparent additional mass, and other parameters.

It was shown in [5] that a jet propagating in a crossflow does not possess the property of similitude. This is evidenced first of all by the fact that, in the construction of lines of equal velocity, the cross sections of the jet change from a circular to a horseshoe shape. Such a change in jet development along its length leads to problems in analytically describing profiles of velocity, temperature, and concentration in its cross sections. In connection with this, it was proposed in [11] that the jet flow region be broken down into three sections, within each of which the flow could be assumed to possess the property of similitude. Meanwhile, according to the data in [11], the determining change in the cross-sectional shape of the jet occurs in the initial section. However, this was not confirmed by the experiment in [7]. In the present work, we attempt to analytically determine the above jet parameters within a broad range of values of the hydrodynamic parameter $Q$ ($4 \leq Q \leq 400$). The method of calculation is based on several assumptions: the jet axis is the locus of the points where the velocity for each section normal to the direction of the jet is maximal; the jet is bounded by the surface on which the excess velocity in the direction of the axis decreases to less than a specified low value.
Fig. 1. Drawing (a) and trajectory (b) of jets: 1-8) $q = 4.75; 10; 16; 25; 50; 125; 200; 400$, respectively; clear points $-$ [9]; dark points $-$ [10]; curves $-$ calc.

We will examine an isothermal jet of incompressible fluid issuing from a circular hole normal to the crossflow. The propagation of the jet in the uniform crossflow is described in a rectangular system of coordinates, $X, Y, Z$, with its origin at the center of the hole from which the jet escapes (Fig. 1a). The equation of equilibrium of the forces acting on an isolated element of the jet projected onto a normal to the jet axis has the form [1]

$$dP = - d\Phi,$$  \hspace{1cm} (1)

where $dP$ is the projection onto the normal of the force from the pressure field acting on the side of the element; $d\Phi$ is the centrifugal force which arises with the motion of the element over the curvilinear trajectory. It can be described thus:

$$d\Phi = \frac{\rho U^2 S}{R} dt,$$  \hspace{1cm} (2)

where $U$ is the mean mass velocity, determined from the formula

$$U = \frac{1}{S} \int \int u ds.$$

The force of the pressure $dP$ is described by analogy with flow about a solid and is proportional to the characteristic frontal area and the velocity head, which is calculated from the projection of the crossflow velocity onto the axis normal:

$$dP = C_n \frac{\rho U^2}{2} \sin^2 \alpha dz dl,$$  \hspace{1cm} (3)

where $C_n$ is the drag coefficient, dependent on the dynamic heads of the jet and flow.

Allowing for (2) and (3), Eq. (1) takes the form

$$C_n \frac{\rho U^2}{2} \sin^2 \alpha dz dl = \frac{\rho U^2 S}{R} dl.$$  \hspace{1cm} (4)

Equation (4) is solved using various assumptions regarding conservation of momentum. Analysis of calculated results shows that assumption of conservation of the momentum projection along the $Y$ axis or constancy of excess momentum along the jet does not lead to satisfactory agreement with the empirical data, especially at low $q$. At high $q$, the above assumptions give results close to the experimental findings. Thus, we will use the assumption of constant total momentum along the jet [4], which leads to the best agreement between the calculated and experimental data:

$$\rho U^2 S = \rho_0 U^2 S_c = \text{const}. $$  \hspace{1cm} (5)

Allowing for the assumption (5), Eq. (4) is written:

$$C_n \frac{\rho b_z}{2} \sin \alpha = - \frac{\pi q}{2}. $$  \hspace{1cm} (6)