CALCULATION OF PARAMETERS OF A FLAT TURBULENT JET IN A DEFLECTING STREAM

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On the basis of the solution of the problem of a flat turbulent jet in a deflecting stream obtained earlier by the author a method is suggested for calculating the parameters of the main section of such a jet with allowance for the rarefaction occurring behind it. The amount of rarefaction was determined from an experiment and is accounted for by a second empirical constant. The results of a calculation by the proposed method are in satisfactory agreement with the experimental data.

The solution of the problem of a flat turbulent jet in a deflecting stream is presented in [1, 2]. The results obtained in these works show that when there is satisfactory agreement for the velocity \( u_m \) at the axis of the jet and for the ordinates \( \delta_1 \) and \( \delta_2 \) of its boundaries the axis of the jet is bent less than indicated by the experimental results. The suggestion was made in [2] that this difference between experiment and calculation is explained by the fact that rarefaction behind the jet was not taken into account. In the present report an attempt is made to allow for this rarefaction.

To a certain extent the flow in the zone behind the jet is analogous to the flow in the "dead" zone behind a plate mounted at right angles to the impinging stream. From physical considerations one should expect that the rarefaction behind a jet must be somewhat less than behind a plate. In fact, when a deflecting stream flows around a jet the return currents behind it are stimulated with less velocity than behind a plate. This occurs because the velocity in the jet which separates the "dead" zone from the rest of the flow decreases steadily, and if the return currents are intense then the rarefaction behind the jet must be somewhat less than behind a plate.

From the results of the experiment described in [2] the maximum relative rarefaction behind the jet was constructed as a function of the ratio of the initial velocity \( u_0 \) of the jet to the velocity \( v_\infty \) of the deflecting stream (Fig. 1). It turned out that this rarefaction is approximately constant and equal to \( 2\Delta p/\rho v_\infty^2 = 0.7 \). The value of the rarefaction obtained in this way can be considered as a second empirical constant. The rarefaction found from the experiment was used in the calculation whose results are presented in Figs. 2 and 3. It is seen from a comparison with the experiment that with the introduction of a correction for the rarefaction the results of the calculation agree satisfactorily with the experimental data for all the parameters examined.

Values calculated on an electronic computer for the ordinate of the exterior (facing toward the stream) boundary \( \zeta_0 \) of the jet, the distance \( x \) along the axis of the jet, the radius of curvature \( R \) of the axis, and the relative velocity \( u_0/v_\infty \) at the exterior boundary of the jet as functions of the coordinate \( \xi \) and the value

### Fig. 1. Dependence of relative rarefaction on ratio of initial velocity of jet to velocity of deflecting stream (black circles were obtained in a study of the main section of the jet, open circles in a study of the initial section).
Fig. 2. Comparison of calculated axis of jet with experimental data: solid line, calculation for \(u_0/V_\infty = 5\); broken line, calculation for \(u_0/V_\infty = 9.81\); 1) experiment [4] at \(u_0/V_\infty = 10\); 2) [2] at \(u_0/V_\infty = 9.81\); 3) [2] at \(u_0/V_\infty = 5\); 4) [5] at \(u_0/V_\infty = 5\); 5) [4] at \(u_0/V_\infty = 5\).

Fig. 3. Comparison of calculated boundaries of jet and velocity at axis of jet obtained on electronic computer with experimental data at \(u_0/V_\infty = 5\): solid lines; calculations: 1) experiment [2]; 2) [3].

Fig. 4. Comparison of ordinates of jet and velocity at axis of jet calculated by proposed method with experimental data [3] \((u_0/V_\infty = 7.06)\).

K_2 = (u_0/V_\infty)^2b_02 are presented in Table 1. (Here \(\xi, \zeta\) is an orthogonal coordinate system whose axes are directed along the direction of the deflecting stream \(\xi\) and along the direction of discharge of the jet \(\zeta\), while the origin of the coordinates is located at the fictive source; \(b_02\) is the width of the interior downstream part of the nozzle cut relative to the width of the nozzle \(b_0\). This quantity is determined from the solution for the initial section [2]. To a first approximation it can be set at 0.5.)

The calculations showed that the dependences presented in Table 1 are practically unchanged during variation of the empirical constant \(\beta\) in the range 0.08-0.1 usually encountered. The data presented in the table can be used for a simplified calculation of the parameters of a jet in a deflecting stream in the range of variation in \(u_0/V_\infty\) from 3.5 to 10. Such a simplified calculation can be organized in the following way. Through interpolation from Table 1, \(\xi_0, x, R,\) and \(u_0/V_\infty\) as functions of \(\xi\) are determined for a given \(K_2\). These are the auxiliary values for calculation by the equations presented in [1] and [2]. Since the dependence of \(\delta_2\) on \(x\) is close to linear, as seen from Fig. 3, one can assume for simplicity that this dependence is the same as that in a submerged jet, i.e.,

\[
\delta_2 = -\frac{225}{8} \beta x. \tag{1}
\]

Thus, with the help of Eq. (1) and the dependence \(x(\xi)\) found from Table 1 one can find the ordinate \(\delta_2\) of the interior boundary of the jet as a function of \(\xi\). Then \(\delta_1\) and \(u_m/V_\infty\) are determined from the equations obtained in [1] for the values of \(\delta_2\) found using Eq. (1):

\[
\left(\frac{u_m}{V_\infty}\right)^2 = \frac{K_2}{\delta_2 \left(\frac{33}{112} - \frac{5}{84} \delta_1 \frac{R}{\delta_1}\right)}, \tag{2}
\]

\[
\delta_1 = -\delta_2 \left(1 - \frac{u_0}{u_m}\right)^{2/3}. \tag{3}
\]