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RELATIONSHIP BETWEEN AVERAGE (OVER TIME) VELOCITY AND LONGITUDINAL TURBULENT PULSATION OF VELOCITY ON THE AXIS OF A JET

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Results are presented from an experimental study of a submerged axisymmetric jet with different initial conditions. Criteria are found for determining the location of the point with maximum pulsations on the jet axis.

The microstructure of submerged jets has recently become the subject of numerous investigations which have attempted to discover the mechanism of turbulent heat and mass exchange [1-4 et al.]. For example, it has been established [1, 2, 4] that in the lateral flow of a submerged jet around a plate, heat exchange in the region of the stagnation point reaches its maximum value when the plate is located about 8D from the outlet section of the jet. This distance coincides with the position on the jet axis at which $(\overline{u'^2})^{1/2}$ has a maximum value. It was also shown in [1, 2, 4, et al.] that heat exchange is intensified with an increase in the initial turbulence. A change in the initial turbulence affects both the macrostructure and microstructure of the jet [2, 4, 5]. Most important in this regard is the fact that the location of the point on the flow axis at which $(\overline{u'^2})^{1/2}$ has its maximum depends on the initial turbulence. When the latter is greater than 5%, this point already no longer coincides with the section $x/D \approx 8$. Thus, it is very important that another criterion be found to determine the

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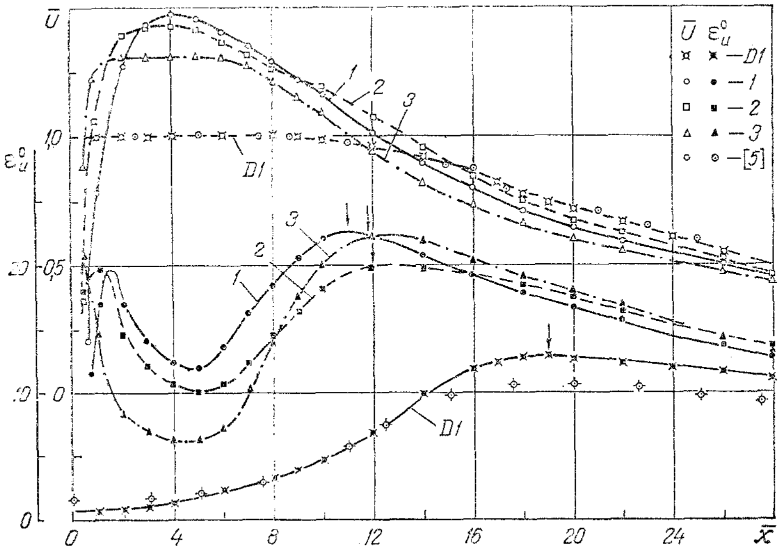

Fig. 1. Change in $\overline{U}$ and ε_u^0 along axis of submerged axisymmetric jet D1 (Vitoshinsk nozzle D = 50 mm, $\overline{u}_0$ = 50 m/sec, ε_u^0 = 0.54%) and in the flow after an agitating grid: 1) D = 50 mm, $\overline{u}_0$ = 10 m/sec, d = 12.41 mm, t = 15 mm, b = 8 mm, α = 0.553; 2) respectively, 117 mm, 10 m/sec, 36.1 mm, 38 mm, 8 mm, 0.65; 3) respectively, 117 mm, 10 m/sec, 12.41 mm, 15 mm, 8 mm, 0.553. ε_u^0, %.

coordinates of this point, and this is the objective of the present study.

The existence of a generalized criterion which would not be dependent on a change in the initial conditions has been confirmed by well-known data [5-7] which show that turbulent pulsations of velocity through the radius of the flow in its initial section (when there is no grid in the outlet section of the nozzle) have a maximum in the region r = 0.5D. It is logical to look for a similar dependence on the axis of the flow.

The experiments were conducted under the following conditions: a) initial turbulence changed from 0.5 to 8% with a uniform velocity profile in the outlet section of the nozzle; b) the boundary layer in the outlet section of the nozzle had different thicknesses (we used a Vitoshinsk nozzle and a circular nozzle); c) the diameter of the nozzle (tip) was changed from 10 to 117 mm; d) different grids of the flat-plate-with-holes type were installed at the nozzle outlet.

The experimental unit, grids, and measuring instruments are described in [8], while the features of the flow after the grid are described in [9-11]. The results of the studies under the above-noted conditions show that $(\overline{u'^2})^{1/2}$ reaches a maximum along the flow axis in the section where $\overline{u}$ takes values roughly equal to $(0.72\text{-}0.75)u_c$.

In the case of flow without a grid, $\overline{u}_c \equiv \overline{u}_0$. With the use of a grid, after which no core is formed in the flow [10] (Fig. 1, curves 1 and 2), $\overline{u}_c \equiv \overline{u}_{max}$.

All this is also confirmed by analysis of the results obtained by other authors with a different initial turbulence [2, 5, 6], the presence of acoustic effects [5], or a different shape of tip [12].

Figure 1 shows the curves obtained for $\overline{U}(\overline{x})$ and $\varepsilon_u^0(\overline{x})$ on the flow axis after a grid (curves 1 and 2 are for jets without a core, curve 3 — for a jet with a core [10]). Empirical curves D1 are also given for a submerged axisymmetric jet without a grid in the outlet section in which Re = $1.66 \cdot 10^5$, D = 50 mm, and ε_u^0 = 0.54%. The agreement of the test data for $\overline{U}(\overline{x})$ (curves D1) with well-known data from [5] is very good. This is confirmation of the reliability of the results obtained here.

The arrows next to the curves of $\varepsilon_u^0(x)$ denote the points at which ε_u^0 has a maximum value.

Thus, the criterion obtained for determining the point along the axis of the initial section of a jet at which turbulent pulsations are maximal makes it possible, together with a well-known criterion, to determine the region of maximum turbulent pulsations in the radial direction and to predict the site of the most intensive heat and mass exchange in a submerged axisymmetric jet from the field of the average velocity over time.

NOTATION

x, distance along flow from outlet section of nozzle; $D = 2r_0$, outlet diameter of nozzle or grid diameter; r, radius; d, diameter of openings of agitating grids; t, distance between grid openings; b, grid thickness; α, coefficient of through cross section of grid; $\bar{u}$, average velocity at a point over time; $\bar{u}_c$, average (over time) velocity at a point of the flow core after a grid [11]; u_0, average (over cross section) velocity at outlet of nozzle or in front of grid; $(\overline{u'^2})^{1/2}$, rms value of longitudinal turbulent pulsation of velocity; $\varepsilon_u^0 = (\overline{u'^2})^{1/2}/\bar{u}_0$, dimensionless velocity at points of the flow; $x = x/r_0$, dimensionless distance.

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