INTENSITY OF TURBULENCE IN THE CORE OF AN IMMERSED JET AND BEHIND GRIDS

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We discuss the results from the measurement of turbulence intensity of a flow in the core of an immersed jet and behind grids installed in a tube.

The authors studied the effect of the parameters of a stream of air (temperature and velocity) on the nature of the variation in ε in the core of an axisymmetric jet discharging from a tube 150 mm in diameter, with ε_0 = 4-5%, as well as behind turbulization grids installed in a tube 180 mm in diameter. The blockage factor for the tube cross section by the grids was equal to S = 0.74-0.87.

The basic dimensions of the grid and the pattern of orifice position are shown in Fig. 1. The grids are 8 mm in thickness. The velocity of the air flow varied from 20 to 80 m/sec, while the temperature varied from 300 to 873°K. The intensity of the turbulence was measured by a diffusion method. A source (a tube with an outside diameter of 1.4 mm) set into the flow supplied the helium whose concentration profile was measured at a distance of h = 20-30 mm from the source.

The gas sample was taken from the flow by means of a tube similar to the tube source. The helium source and the tube for the sampling of the gas could be moved, both simultaneously and separately, in the axial and radial directions. The helium concentration in the sample was determined by means of a gas analyzer.

The helium concentration profiles that measure the various distances from the source are rather well described by a Gauss curve. The intensity of the turbulence was calculated from the relationship $\varepsilon = \sqrt{\overline{Y^2}}/h$, while the dispersion $\sqrt{\overline{Y^2}}$ was defined as the half-width of the helium concentration profile C(y) for the ordinate of the concentration C(0) at the axis, equal to C(y)/C(0) = 0.607.

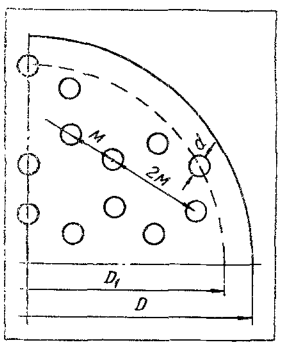

Fig. 1. Diagram showing positions of grid orifices:

Grid No.	M, mm	d, mm	No. of orifices	D_1, mm	S
1	15	9	52	160	0,79
2	25	16	20	110	0,84
3	10	7	166	170	0,74
4	15	7	52	160	0,87

Here we initially studied the effects on the quantity $\sqrt{\overline{Y^2}}$ as exerted by the source and the tube for the taking of the samples, by the helium flow velocity, and by the removal of the gas sample. The effect of these factors on $\sqrt{\overline{Y^2}}$ was taken into consideration in processing the measurement results. The effect of molecular diffusion under the conditions of the experiments was slight, and in processing these data we made no effort to introduce a correction factor for this effect. The relative error in the determination of the dispersion did not exceed 5-6%.

The measurement results for $\varepsilon(x)$ in Fig. 2a show that the intensity of the turbulence in the core of a free jet along the axis of the flow does not remain constant, but begins to increase in the case of an isothermal jet at a distance of $x \approx 1.6$ D from the tube outlet. With an increase in the flow temperature T_0 the increase in the intensity of the turbulence begins at shorter distances from the tube outlet. In all cases, the segment x_{in} in which ε = const was shorter by a factor of approximately 2.5 than the initial segment measured and calculated from the data of [1]. We observed

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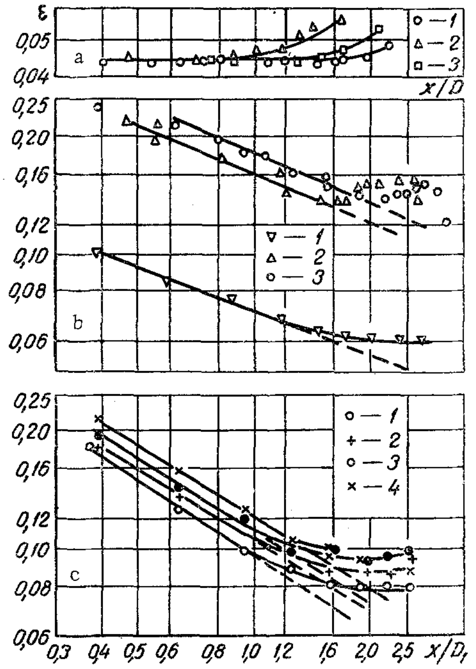

Fig. 2. Change in the intensity of turbulence along the axis of the flow: a) in an immersed jet, V = 37.5 m/sec: 1) T_0 = 295°K; 2) 873; 3) 573); b) behind grids Nos. 3, 2, and 4, T_0 = 295°K; 1) No. 3, Re = $5.5 \cdot 10^4$; 2) No. 2, Re = $12.6 \cdot 10^4$; 3) No. 4, Re = $11 \cdot 10^4$); c) behind grid No. 1: 1) Re = $2.4 \cdot 10^4$, V = 8 m/sec, T_0 = 295°K; 2) Re = $3.6 \cdot 10^4$, V = 40 m/sec, T_0 = 575°K; 3) Re = $4.5 \cdot 10^4$, V = 15 m/sec, T_0 = 295°K; 4) Re = $12.0 \cdot 10^4$, V = 40 m/sec, T_0 = 205°K.

no effect on the part of low velocity on the magnitude of x_{in}. The increase in the intensity of turbulence in the core of the jet is apparently associated with the intermittence of the flow [2] and is determined by the penetration of large-scale vortices (formed in the mixing zone) into the core of the jet. The results from the measurement of the intensity of flow turbulence behind the grid are shown in Fig. 2b, c. These data show that the initial level of turbulence intensity is the higher, the greater the factor S which shows the extent to which the grid blocks the cross section of the tube. At distances close to the grid, the change in ε along the flow is described [3] by the well-known relationship

$$\varepsilon^2 \sim x^{-n}.$$

The magnitude of the exponent n is equal approximately to 1.2 for flow behind grid No. 3, and it is equal to 0.8-0.9 behind grids Nos. 1, 2, and 4.

Measurements of the average-velocity fields behind the grids showed that because of countercurrent zones near the tube walls ($D_1 < D$) the velocity of the flow in the central portion diminishes with distance from the grid. It is apparently this phenomenon that results in some reduction in n, as found for grids Nos. 2, 3, and 4. With increasing distance from the grid the rate at which turbulence is damped is reduced, and in a number of cases we actually observe a brief increase in ε (grids Nos. 1, 2, and 4). This phenomenon can be explained by the penetration into the central region of the flow of the vortices which are formed in the mixing zone of the main flow and by the countercurrents of air behind the grid at the walls of the tube. The dimensions of the countercurrent zones are determined by $D - D_1$ (see Fig. 1), and the increase in the intensity of flow turbulence behind the various grids (Fig. 2b) therefore begins approximately with identical values for x/D_1:

$$x/D_1 \approx 1.6.$$

Figure 2c shows the results from our investigation of the effect exerted by the flow parameters (velocity and temperature) on the intensity of turbulence behind the grid. An increase in the Reynolds number leads to some increase in the intensity of turbulence. A similar result had been achieved earlier in [4, 5], where the Re number varied with the change in pressure.

NOTATION

C	is the helium concentration;
D	is the tube diameter;
D_1	is the diameter of the perforated portion of the grid;
d	is the diameter of the grid orifice;
h	is the distance from the helium "source" to the gas-sampling tube;
M	is the spacing between the grid orifices;
$S = 4F/\pi D^2$	is the factor expressing the blockage of the tube by the grid;
F	is the area of all grid orifices;
T_0	is the flow temperature;
V	is the flow velocity;
x	is the direction along the axis of the flow;
x_{in}	is the length of the segment of the immersed jet, where ε = const;
y	is the direction perpendicular to the flow;
$\sqrt{\overline{Y^2}}$	is the dispersion of the helium concentration;
ε	is the intensity of flow turbulence;
ε_0	is the intensity of flow turbulence at the tube outlet.

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