# TWO SPONTANEOUSLY ALTERNATING REGIMES OF VORTEX FLOW ABOVE A PLANE

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In [1] it was shown theoretically that for a strongly swirled jet two stable flow regimes, changing into one another upon an outside disturbance, are possible at the same Reynolds number. An experimentally observed phenomenon of hysteresis of flow in a vortex chamber was described in the literature [2], but we found no information about velocity profiles for such regimes of vortex flow.

In the present communication we give experimental velocity profiles for two states of vortex flow, obtained in the course of a study of the interaction of a swirled jet with a plane.

The swirl generator (Fig. 1) was a diaphragmless vortex chamber with a diameter D = 50 mm and a height H = 80 mm. The main vortex-generating air stream entered the helical swirler, located in the upper part of the chamber, through a connecting pipe with $d_1$ = 8 mm. In addition, a suction connecting pipe with $d_2$ = 10 mm was located in the cover the the chamber to intensify the ascending stream. The generator was placed at a height h above the plane of 50 mm.

The structure of the vortex flow was investigated with a two-component, laser Doppler velocity meter with an LADO-2 optical unit. Information on the measurement procedure and concrete features of the apparatus is given in [3, 4]. The realization of this method enabled us to prevent distortion of the pattern of vortex flow by the introduction of some probe and to measure two projections of the velocity vector at once. Salt particles with an average diameter $d_{50} \approx 0.5$ μm introduced into the stream served as scattering centers. The particles were created from a 5% NaCl solution in an aerosol source operating on shock-action atomizers. The flow rate of the peripheral vortex-generating stream was $Q_1 = 2.3 \cdot 10^{-3}$ kg/sec while that of the stream sucked through the connecting pipe in the cover was $Q_2 = 0.8 \cdot 10^{-3}$ kg/sec. Making the stream visible showed that the flow had a turbulent character in this case.

For the above-indicated geometrical and flow-rate parameters we discovered the existence of two flow regimes, differing in the profiles of vertical velocity and changing into one another spontaneously (i.e., without artificial disturbances). Each of the regimes discovered had a quasi-steady character, in which precession of the core of the vortex relative to the geometrical axis was not observed. In Fig. 2 we give profiles of the vertical velocity for the cross section z = 10 mm (reckoned from the plane). As can be seen, the values of the velocity in these regimes differ almost twofold in certain regions.

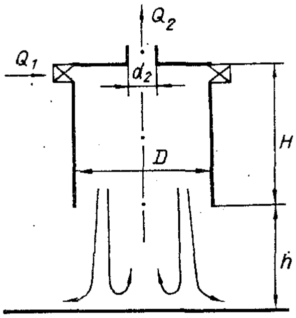

Fig. 1

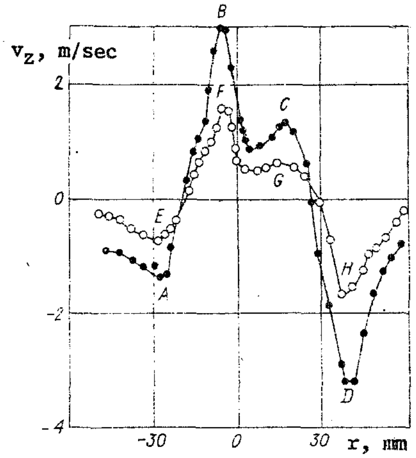

Fig. 2

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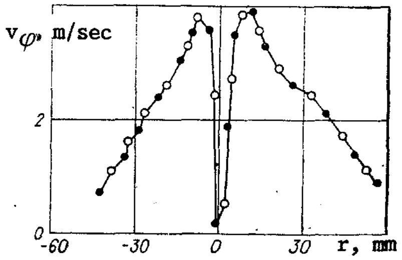

Fig. 3

Differentiation between these flow regimes was done as follows. Since the velocity was measured at an individual point at each instant, the fact of the existence of two regimes of vortex flow was first revealed in those regions where there is a considerable difference in the velocity, such as at r ~ 40 mm (Fig. 2). The characteristic time of existence of regime I (dark points) was 2-3 min, while that of regime II (light points) was about two to four times longer, although no periodicity was observed in the change of regime. The time of the transition from one regime to the other does not exceed the time constant of the measurement system (~1-3 sec). It was also necessary to verify that the profiles of vertical velocity corresponding to the two flow regimes pass through the points A, B, C, D, and E, F, G, H (rather than through A, F, G, D, for example) (see Fig. 2). For this we performed rapid scanning over the entire cross section of the vortex during the existence of regime II (more stable in time) and measured the velocities at the radial coordinates corresponding to points E, F, G, and D (−30, −10, 10, and 40 mm). This process was repeated to avoid errors.

It is interesting to note that we could not reveal differences in the distributions of the tangential velocity component to within the experimental errors (Fig. 3). The profile given in the figure is characteristic for a strongly swirled jet and pertains to both regimes of interaction of a vortex with a plane.

Because of a certain asymmetry of the flow, an exact calculation of the flow rates through cross sections by integrating profiles of the vertical velocity component is difficult. But approximate estimates showed that in regime I the gas flow rate in the ascending stream from its origin in the boundary layer to its entry into the vortex changer hardly varies, i.e., the ascending stream does not exchange mass with the peripheral descending stream. In this case the vortex generator forms the entire ascending flow directly from the surface, or more precisely, from the facing boundary layer above the plane. In regime II in the lower part of the ascending stream there is radial flow from the periphery toward the axis, so that only part of the mass enters the ascending stream from the boundary layer. The rest of the flow rate is made up through the deflection of part of the peripheral annular jet.

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