STUDY OF VELOCITY FIELDS IN VORTEX DUST COLLECTORS

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Results are given of experimental studies of velocity fields in vortex dust collecting apparatus.

Most theoretical studies of the motion of solid particles in rotational gaseous flows assume the gas to be ideal. Consequently it has not been possible to predict or explain the occurrence of radial inward or upward flows in vortex chambers. A possible model for the turbulent flow of viscous gases in such chambers was therefore suggested [1]. From this, equations which allow for their constructional features and operational parameters have been derived to enable calculation of the velocity field.

The results are given here of an experimental study of the accuracy of the predictions of these equations [1]. Experimental conditions and notation are as previously [1].

Tests were made with chambers of five different diameters: 200, 300, 400, 500, and 600 mm. All had the same length of 2.5 m. The diameters of turbulence promoters varied in steps of 100 mm from 100 to 600 mm with the chamber diameter. The ratio of the dimensions of all promoters used was 0.3. The angle β at which their blades were set was varied from 10° to 45°. The pressure drop across them was 390 mm water column and in the inlet sprayers 320 mm water column.

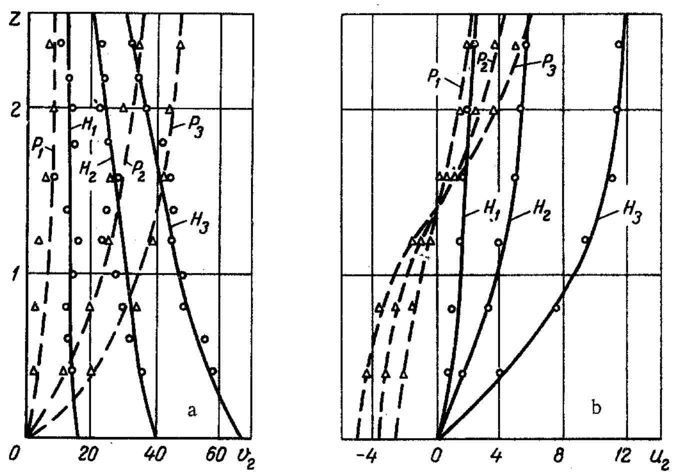

Fig. 1. Plot of changing circumferential tangential velocity components of gas flow (a) and radial velocity components of gas (b) due to turbulence parameter (solid line) and secondary gas (dashed line) along chamber height depending on pressure drop of turbulence parameter and pressure drop at sprayers.

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TABLE 1

D, mm	100	200	300	400	500	600	700	800	900	1000	1200	1500	2000
$a\times 10$	1,05	0,95	0,90	0,86	0,83	0,80	0,78	0,76	0,74	0,73	0,72	0,71	0,70

The velocity field was measured by a symmetrical five head sensing probe with the outputs measured by micromanometer. The errors in the measurements did not exceed 10%. N. T. P. air was used as the working medium for the tests.

Figure 1a presents the data for the circumferential tangential velocity along the chamber length (continuous lines) for $\beta = 20°$; d = 1; $v = 18.2 \cdot 10^{-6}$ m^2/sec produced by the turbulence promoter for various pressure drops and for all the chamber diameters. In all figures the lines give theoretical [1] values and the dashes give the present experimental values.

It should be noted that the measurements showed the tangential velocity to be directly proportional to the cosine of the turbulence promoter blade angle over the whole range of the increasing pressure loss produced by the promoter.

Figure 1b presents data for radially outward velocity (continuous lines) produced by the rotation in the gas flow by the turbulence promoters. The existence of such velocities can facilitate the collection of dust and may therefore be considered advantageous.

The tangential velocities produced by the discharge of the air into the chamber through its sprayers on its periphery depend on its diameter. This dependence is accounted for by the varying turbulence factor of the gas in the well known relationship [2, 3]

$$w = w_f \left(\frac{0.48}{\frac{ax}{D_f} + 0.145} \right). \quad (1)$$

The variation of the turbulence factor a with chamber diameter is as follows.

In Fig. 1a the dashes show the circumferential velocities along the length of the chambers produced by the gas flow in the jets from the sprayers. The sprayer diameter was 20 mm and its angle was 30°. It should be noted that change of this angle by ±10° did not change the flow in the chambers. Change in the distribution between the pressure drop across the sprayers did have a considerable effect on the flow. This was however so complex that despite the collection of extensive experimental data it was not possible to present a coherent description of this effect.

The previous workers [1] also found that in vortex chambers with intense turbulence there are regions with radially inward flow. Similar results were detected and measured in the present study.

Figure 1b (dashed line) presents the velocities of gas flows towards the axis of the chamber. As can be seen from this figure (dashed lines) the regions in which such flows occur are extensive.

The presence of these flows seriously interferes with the dust collection. Any attempt to improve the flow of gas being purified by secondary flows with high energy will increase the radially inward velocities so much (by up to 50% of tangential velocities) that the reverse effect can be caused.

This should be taken into account when considering the pressure drop distribution between the turbulence promoters and the secondary flow.

Figure 2a shows the variation in tangential velocity with radial position in the chamber for various ratios of the turbulence promoter diameter to the chamber diameter. For the ratio $\varepsilon = 1$ it was verified that as can be seen for $\bar{r} = 0.7$ in Fig. 2b (experimental data) the ratio $v_1/v_{1\,max}$ is in accord with the assumption of rotation as a solid body.

It was established both theoretically and experimentally that the turbulence produced by the promoters causes the flow in the center to be downwards, i. e. against the main direction of the flow. At the same time, the vortex generated by the secondary flow draws the central part of the gas towards the axis and produces strong upward velocities. This has the further undesirable effect of either reducing or eliminating

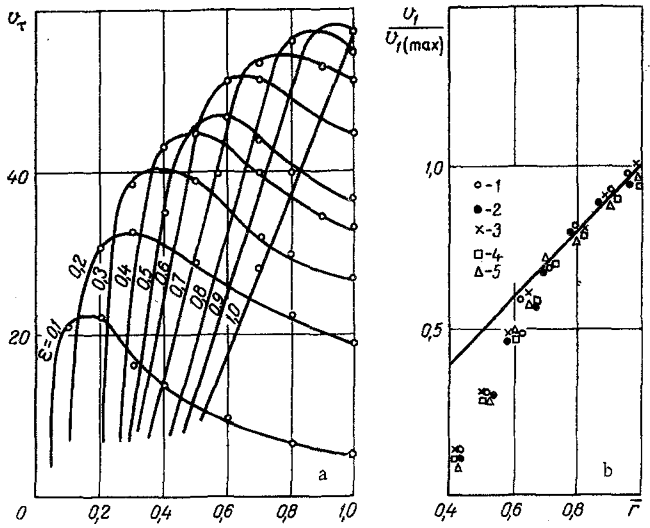

Fig. 2. Plot of changing tangential velocity along chamber radius depending on turbulence parameter diameter to chamber diameter ratio (a) and plot of changing tangential velocity to its maximum value ratio along chamber radius (b).

the effect on the gas of the turbulence promoters. The existence of this radial and upward flow in the center of the vortex chamber and the continuity equation show that at the top of the chamber there must be regions of outward flow and that at the walls there must be downward flow. It follows therefore that during operation of the chamber, its vortex must be toroidal in shape. The undesirable effects of such a vortex on dust collection are apparent.

It remains only to point out that this structure of the flow in the vortex is produced by intense turbulence and can prevent the removal of fine dust from gas flows through vortex dust collectors.

NOTATION

Z is the height of apparatus;
v_2 is the tangential velocity behind turbulence promoter, m/sec;
u_2 is the radial velocity behind turbulence promoter, m/sec;
β is the angle at which promoter blades are set, deg;
d is the relative diameter of chamber;
ν is the kinematic viscosity of gas, m^2/sec;
w is the velocity at the chamber point under study, m/sec;
w_f is the velocity of gas outflow from a sprayer, m/sec;
a is the turbulence factor;
x is the distance between sprayer and point under study, m;
D is the diameter of chamber, m;
D_f is the diameter of sprayer, m;
v_1 is the tangential velocity behind sprayer, m/sec;
u_1 is the radial velocity behind sprayer, m/sec;
ε is the promoter diameter to chamber diameter ratio.

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