THE PROBLEM OF HYDRAULIC RESISTANCE IN BLOWERS

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We discuss the author's concepts of the mechanism by which the flow velocity, the diameter, and the dust content affects the hydraulic resistance of blowers.

Our investigations have demonstrated that the curves for the coefficient of hydraulic resistance ζ_b for blowers as a function of the flow velocity w_b are ascending in nature (Fig. 1). The shape of these curves can be explained by the effect exerted by the frictional resistance of the wall on the intensity of the swirling. We know that the lower the velocity (the Reynolds number), the greater the coefficient of friction. Consequently, the smaller w_b, the greater the decelerating effect which the walls of the blower exert on the rotation of the flow. Since the basic losses in the blower are associated with the rotational motion of the flow in general and with the loss of kinetic energy of the rotating flow in the exhaust section, a reduction in swirling intensity will lead to a reduction in the overall coefficient of blower resistance. This explanation is in complete agreement with the theoretical conclusion by Klyachko [1] as to the unavoidability of an increase in the coefficient of resistance for equipment with rotating liquid flow when the viscosity of the liquid is reduced, or – and this is the same – with an increase in the Reynolds number.

It follows from the above that with a constant velocity and dynamic viscosity the coefficient of blower resistance must increase as the diameter D increases.

An analogous effect must be the result from a change in the relative roughness of the walls of the blower or in the relative magnitude of the local projections (welding spots, seams, etc.).

The total coefficient of resistance ζ_b^{tot}* as a function both of the blower diameter D (for $w_b = 4$ m/sec) and as a function of the Re number for various D is plotted in Fig. 2. The nature of these functions is precisely as described above. At the same time, we see from the curve for $\zeta_b^{tot} = f(\mathrm{Re})$ that the points pertaining to the various diameters do not group about a single common curve, but separate precisely in accordance with the diameters. Here, the greater D the higher the corresponding curve. It is precisely by the effect of the surface condition of the blower walls that we explain this circumstance. Indeed, if the blowers of various diameters are made of identical material, the relative roughness and the relative magnitude of the local projections are the smaller the larger the diameter. Consequently, the greater D, the smaller the decelerating effect of these projections. Hence the swirling of the flow is more intense and the greater the value of ζ_b^{tot}. The comparatively steep rise in the curve $\zeta_b^{tot} = f(D)$ in Fig. 2 below $D \cong 400$ mm should thus be explained not only by the effect of Re, but to an even greater extent by the influence of the condition of the wall surfaces.

Numerous experiments by various authors [2-7], as well as our own research (Fig. 3), shows the substantial effect of dust content in the flow on the resistance of the blowers, reducing the latter as the dust content increases within certain limits. The reason for the drop in blower resistance in proportion to the dust content of the flow is explained variously by the different authors: by the reduction in flow turbulence [2-4]; by an increase in the

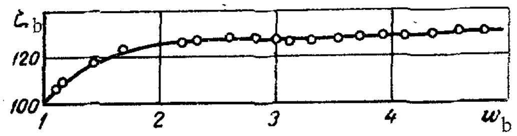

Fig. 1. Resistance coefficient ζ_b of the blower as a function of the velocity w_b (m/sec).

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*$\zeta_b^{tot} = \zeta_b^m + (D/d)^4$ makes provision for additional losses in ram pressure at the outlet when the blower is operating in the discharge regime.

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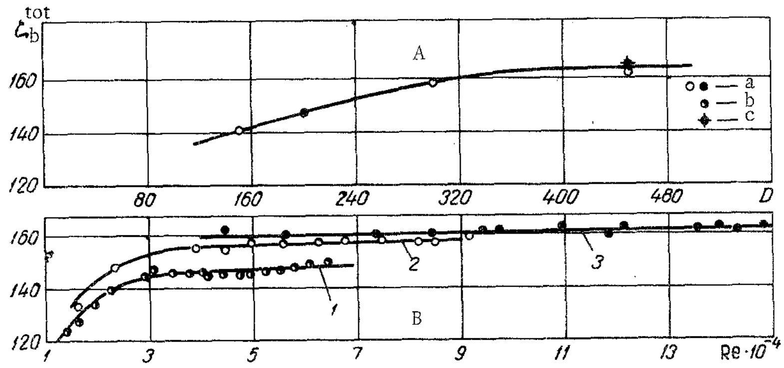

Fig. 2. Coefficient of total resistance for the TsN-15 blower, d/D = 0.59, as a function of the diameter D, in mm (A) and as a function of the Reynolds number Re (B): 1) D = 200 mm; 2) 300 mm; 3) 450 mm; a) Mal'gin experiment; b) Idel'chik experiment; c) Kouzov experiment.

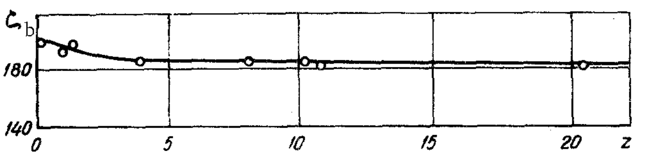

Fig. 3. Coefficient of resistance ζ_b of a group blower as a function of the degree of dust content z in the flow (g/nm^3).

specific weight of the flow containing dust and, hence, by an increase in the momentum; the loss of a fraction of the energy on the transportation of solid particles and a reduction in the fraction of energy expended on swirling the flow [5]; and finally, by a reduction in the viscosity of the medium [6]. It is likely that all of the above factors are active simultaneously. However, in addition to these, and in our opinion, to a considerably greater extent, other factors play a role here. One of these involves the fact that a large portion of the particles suspended in the flow, as is well known, is deposited on the walls of the blower immediately on entry of the flow into the blower and this, primarily, determines the "cleansing" of the flow in the blower. These particles, on losing their velocity, simultaneously begin to decelerate the medium in which they are entrained. In this case it is unimportant how the particles will behave subsequently, i.e., whether they will remain at the wall or at a distance from the wall. Thus, in addition to the above-described effect of conventional friction against the wall we have the analogous effect of the deceleration of the rotational motion of the solid (or liquid) particles settling out on the wall.

It is obvious that the greater the concentration of the particles suspended in the flow, within certain limits,* the more pronounced the described effect, i.e., the greater the reduction in resistance as a consequence of flow dust content.

We should assume that at identical concentrations the larger particles, because of the factors which we have cited, should result in a greater reduction of resistance (within certain limits). With greater particle size, first of all, a substantial portion of the particles will settle out on the wall (the very small particles do not settle out at all), and secondly, the larger-sized particles will offer greater resistance to the flow (as in the case of larger roughness irregularities).

The explanation proposed by the author of [6] for the reduction in blower resistance in proportion to the dust content of the flow as a consequence of a reduction in the viscosity of the medium seems to us to be without foundation. The reduction in viscosity may significantly affect only the friction losses, since the coefficient of friction is a function of the Reynolds number which includes the coefficient of dynamic viscosity. However, the basic losses in the blower, generally speaking, do not directly depend on Re. The reduction in viscosity cannot therefore directly nor significantly affect the overall resistance of the blower, although it indirectly affects the overall resistance of the blower, but in precisely the opposite direction – it serves to increase this resistance. Indeed, all other conditions being equal, a reduction in viscosity leads to an increase in the Reynolds number. However, this leads to a reduction in the friction drag and, consequently, as demonstrated above, it leads to an increase in the overall coefficient of blower resistance.

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*Until the losses resulting from the transportation of the suspended particles exceed the considered gain in energy losses.

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