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SEPARATION OF PARTICLES IN CHANNELS ROTARY ENGINE

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Abstract. The article considers the separation of particles in channels with different relative length. It is shown that the intensity of turbulence at the inlet section of the channel varies considerably in its length. The dependence of the turbulence damping along the channel expressing by fraction of the distance is shown. The ratio of the particle separation efficiency out the gas flow in the rotor channel is defined. The values of particle separation efficiency in the channel for the angle $\alpha=\pi/4$ in turbulent aerosol flow is shows, including without mixing the particles.

1. INTRODUCTION

Centrifugal dust separators with additional particles separation in rotor channels are studied in [1−2] but the conclusions about the efficiency of these processes are discrepant. Separation of particles is studied in channels with relative length not higher than l/h = 5÷6. In work [3], the information is that just on this length the strong damping of the «external» turbulence takes place and it is clear that an effective separation should be taken in the channels with the relative length l/h>7. Calculations of particle separation with allowance for turbulence are compared with experiment. In works [3, 4] the different types of rotary machines are described and the results of experimental and theoretical study of the separation of moisture from flowing turbines parts of are given, efficiency of co-channel separation and from the space over the rotor blades at varying geometric parameters of stages of are analyzed. In work [5] there are a description of the structure and a scheme of turboseparator layout for gas condensate liberation from natural gas. A good performance and high efficiency compared with gravity separators are noted, and the same time the turboseparator weight 52 times less than the g gravity separator at the same working condition.

2. EXPERIMENTAL SETUP AND PROCEDURE

The scheme of the centrifugal separator [5] is shown in Fig. 1.

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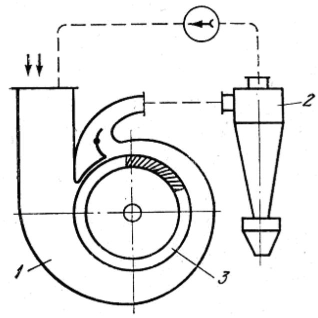

Figure 1. Scheme of the centrifugal separator: 1 – enclosure, 2–external separator, 3 – rotor

The scheme of the rotor is shown in Fig. 2 [5].

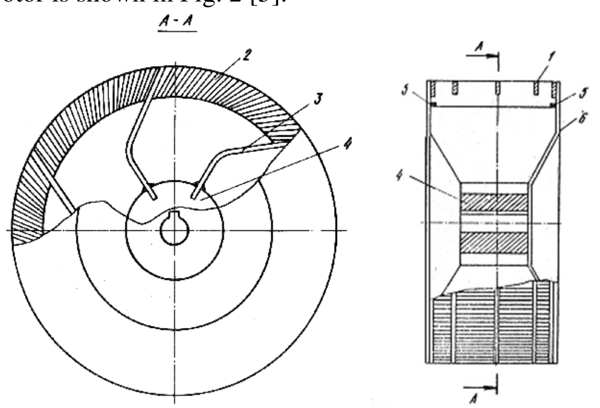

Figure 2. Dust collector rotor: 1– ring-type discs; 2– plates forming channels; 3– bearing blades; 4– hub; 5– clamps; 6– cover

The scheme of particles movement in the channel is shown in Fig. 3.

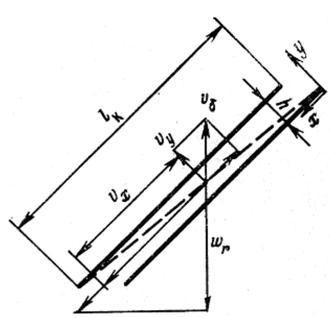

Figure 3. Particles movement in the channel

The components of the particle velocity in the channel by centrifugal force and entrained gas stream forces are shown in fig.3. Coriolis forces are not considered because of their smallness. It is taken that the turbulent diffusion coefficients of particles and gas are identical, the values υ_y, W_x do not depend on x, y.

3. Results and discussion

Turbulent motion of the aerosol in the channel is described by an equation similar to [6] (sign averaging falls)

$$\frac{\partial}{\partial x}(c\upsilon_x)+\frac{\partial}{\partial y}\left(c\upsilon_y - D_y\frac{\partial c}{\partial y}\right)=0 \tag{1}$$

with boundary conditions $c\upsilon_y-(D_y\partial c/\partial y)|_{y=0}=0$, $\partial c/\partial y|_{y=h}=0$, $c(0,y)=c_0$, where $\upsilon_\delta\sin\alpha$; $\upsilon_x=W_x-\upsilon_\delta\cos\alpha$; $\upsilon_\delta=\omega^2R\tau$; $\tau=\delta^2\rho_\delta/18\mu$. Here υ_y, υ_x – averaged particle velocity components in the channel; x, y — coordinates; α — angle of channel inclination to the radial direction; ω— angular rotor velocity; W_x, W_y – averaged gas velocity component in the x-th and the radial direction; δ, ρ_δ – diameter and density of particle; μ – coefficient of dynamic gas viscosity; R – rotor radius; c – the concentration of particles size δ; c_0 – the concentration of particles size δ_0 at the rotor inlet; D_y – coefficient of the particles turbulent diffusion, defined as $D_y=l_y\sqrt{\overline{\upsilon'^2_y}}$ [10], where l_y – the characteristic length of the turbulent flow, equal to the order of channel height h. The last statement is due to the fact that external vortices break up at the entrance to the rotor and they have a scale equal to the distance between the channel plates. At the channel inlet $D_{y0}=h\sqrt{\overline{\upsilon'^2_y}}=hW_*$, where $W_*=\sqrt{\tau_{r\varphi}/\rho}$ – dynamic velocity, expressed through the shear stress at the rotor boundary. The intensity of turbulence at the inlet channel section varies in its length considerably. Damping of the «external» turbulence occurs quickly and under relative channel length x/h=15 and it appears slightly at all levels of initial perturbance [7]. Denominating the channel length of a fraction of the distance l_T t. e. distance of external turbulence damping, it can represent the dependence of the turbulence damping along the channel in a generalized form

$$D_y/D_{y0}=B(\bar{x})=a+(1-\bar{x})^b,\quad \text{where } \bar{x}=x/l_T,\ a\approx 0{,}01,\ b\approx 2.$$

Turbulent diffusion coefficient $D_{y0}=hW_*$ can be defined as follows. In the flowing part of the device between the enclosure and the rotor the turbulent gas flow (just as vortex flow) is realized, where there is a core of quasi-potential distribution of tangential velocities. The equation of the angular gas momentum for flat and symmetric flow looks like $\rho\frac{1}{r}w_r\frac{\partial(w_\varphi r)}{\partial r}=\frac{1}{r^2}\frac{\partial}{\partial r}(\tau_{r\varphi}r^2)$, continuity gas equation is $w_r\cdot r=K_1=$ const, where w_r, w_φ, – radial, tangential components of the gas velocity; $\tau_{r\varphi}$ – turbulent shear stress; ρ – gas density.

Integral of angular momentum equation can be written as

$$\frac{1}{\rho}r^2\tau_{r\varphi}-K_1rw_\varphi=K_2 \tag{2}$$

Based on the general terms of the semiempirical theory of turbulence turbo, we obtain

$$|\tau_{\kappa\varphi}|=-\rho\varepsilon r\frac{d}{dr}\left(\frac{w_\varphi}{r}\right) \tag{3}$$

In the flow zone $rw_\varphi=K_3=$ const from (2) and (3) it follows that ε=const and the relation (3) takes the form $\left(-\frac{K_1}{\varepsilon}+2\right)K_3=K_2$

and when $K_1/\varepsilon\to 2$, $K_2\to 0$ and $K_1 1\varepsilon=2$ the quantity ε depends on K_1 explicitly. Thus the entire zone between the rotating rotor and the external surface K_2=0.

Equation (3) can be written as $\frac{1}{\rho}r^2\tau_{r\varphi}-rw_rrw_\varphi=0$ or $\frac{\tau_{r\varphi}}{\rho}=w_rw_\varphi=w_*^{\,2}$, and at the rotor boundary

$$W_* = \sqrt{W_r U_p} \tag{4}$$

where $U_p=\omega R$, W_r – radial component of the gas velocity at the rotor boundary.

Efficiency of particles separation out of the gas flow in rotor channel is determined by ratio

$$\eta_1 = 1 - \bar{c}_*, \quad \bar{c}_* = \int_0^1 \bar{c}\, d\bar{y}, \tag{5}$$

where $\bar{y} = \frac{y}{h}$; $\bar{c} = \frac{c}{c_0}$.

4. Conclusion

Table 1 shows the efficiency of particle separation in a channel for corner $\alpha=\pi/4$ under turbulent flow aerosol, in parentheses the values of efficiency is indicated without particles mixing.

The table shows that in the range η_1=0,4—0,99 there are a significant difference in the efficiencies.

Table 1. Efficiency of particles separation in the rotor channel

l_k/h	$\omega\tau$	W_r/U_p	
		0.05	0.1
3	$5\cdot10^{-3}$	0.05	0.098
	10^{-2}	0.3(0.33)	0.15 (016)
	0.1	0.96	0.66 (1)
	0.5	099	0.96
9	$5\cdot10^{-3}$	0.4 (0.48)	0.22
	10^{-2}	0.66 (1)	0.4 (0.48)
	0.1	0.99	0.96 (1)
	0.5	0.999	0.99
18	$5\cdot10^{-3}$	0.65 (0.95)	0.4 (048)
	10^{-2}	0.9 (1)	0.65 (0.95)
	0.1	0,995	0.99 (1)
	0.5	0.999	0.999

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