Experimental determination of local and contact device resistance coefficients of the rotor filter device

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ABSTRACT

In this article, the resistance coefficients of local and base grids and basalt fibers laying on the rotor filter in the condition of no liquid supply to the rotor filter device for wet cleaning of dusty gases and gas mixtures are determined experimentally. As a result, it is possible to determine the fluid consumption and energy consumption for optimal values of resistance coefficients and cleaning efficiency by supplying liquid to the device.

Keywords: wet method, device, rotor, filter, basalt, contact surfaces, local resistance, resistance coefficient, gas velocity.

Introduction

The most economical and convenient method for cleaning dust and toxic gases in the gas composition is the wet cleaning process. If we analyze these devices from the point of view of their constructive structure and efficiency, the cleaning efficiency of various industrial dusts is 97-99%. However, the complexity of the structural structure of these devices, the energy consumed in them, and the high hydrodynamic and aerodynamic resistance in the device can be cited as a general drawback. To eliminate the above-mentioned shortcomings and increase the contact surface between the dusty gases and the liquid supplied to the apparatus, a new design of the apparatus was proposed, in which the contact element for cleaning dusty gases by the wet method is covered with basalt fiber [1]. The diagram of the device is presented below (Fig. 1).

Research object

Based on the above requirements, we have developed a new design of a rotary apparatus for the wet cleaning of dusty gases [2]. The calculation scheme and general appearance of this apparatus are presented below (Fig. 1).

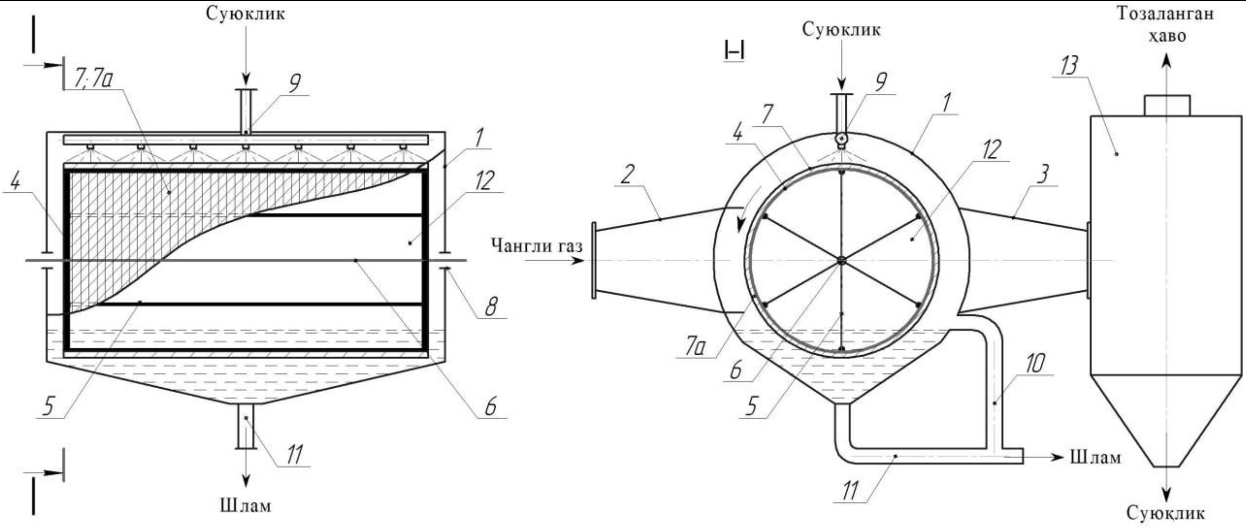

Figure 1. Overview of the device.

1- cylindrical body 1, 2- dust gas inlet pipe, 3- purified gas outlet pipe, 3, 4- support discs, 5- rods, rotor shaft 6, support 7- two-layer steel grid, 7a- fiber material, 8- bearings, 9- nozzles for spraying liquid, 10- level regulating pipe, 11- slurry pipe, 12-rotating rotor 12, 13-droplet catching device.

The type of base steel meshes installed on the rotating rotor contact device of the created device and the type of fibrous material laid between them are selected depending on the physical and chemical properties of the dusty gas to be cleaned, temperature regimes, and the coefficients of hydraulic resistance of the steel meshes and the laid fibrous material and the pressure losses calculated through them, depending on the condition of achieving high cleaning efficiency [2].As a result of theoretical studies, the equation for calculating the total hydraulic resistance of the proposed device was derived [1].

$$\Delta P_{ум} = \lambda_1 \cdot \frac{l_1}{d_{\partial}} \cdot \rho_{см} \cdot \frac{\omega_{см}{}^2}{2} + \left(\Delta \Pi \frac{\Sigma S_c \cdot \delta}{\Sigma S_c \cdot a} + \frac{S_f}{\Delta K \cdot S_r} + \xi_{суюклик} \right) \times \\ \times \frac{\rho_{см} \cdot \omega_{см}^2}{2} + \lambda_2 \frac{l_2}{d_k} \cdot \frac{\rho \cdot \omega^2}{2} + \lambda_3 \cdot \frac{l_3}{d_t} \cdot \frac{\rho \cdot \omega_ч^2}{2} \quad (1)$$

Using this equation, we can write the total resistance coefficient of the device as

$$\xi_{ум} = \xi_{кир} + \xi_{ф.ум.} + \xi_{чик} \quad (2)$$

Here, $\xi_{кир}$ is the coefficient of resistance created by the force of friction when entering the purified gas into the device, $\xi_{ф.ум}$ is the total resistance coefficient of the rotor-filter contact device, $\xi_{чик}$ is the coefficient of resistance created by the force of friction when releasing the purified gas from the device.

The total resistance coefficient of the rotor-filter contact device of the device ξк.ум, the resistance coefficient of the base grids on which the fibrous material is laid is equal to the sum of the resistance coefficient ξc, the resistance coefficient of the fibrous material ξт, and the resistance coefficients formed from the ξсуюқлик sprayed on the contact device. That is:

$$\xi_{ф.ум} = \left(\xi_c + \xi_m + \xi_{суюклик} \right) \quad (3)$$

The gas supplied to the device passes through the base grid and fiber material. The size of the base grids depends on the dimensions of the fiber material laid between them, i.e. length, diameter, and thickness of the layer. The thickness of the laying fiber material is selected depending on the resistance coefficients of its contact surfaces determined through experiments. In this case, when choosing the value of the resistance coefficient, the condition of meeting the requirements of the established standard of cleaning efficiency is taken into account.

Scientific research and theoretical studies were conducted to determine the relative contact surfaces depending on the mass of basalt fibers to be placed in the rotor filter, and the contact surfaces were determined [3].

In this article, experimental studies were conducted to determine the local resistance at the inlet and outlet of the device and the resistance coefficients of the basalt fiber-filled contact element in the absence of fluid.

The results obtained

To lay the basalt fiber filter on the rotor of the apparatus, a support grid with a square hole size a=1.2 mm and a wire thickness δ=0.25 mm was selected. Brand X18H10T (Fig. 3). Lower and upper supports were formed from the grid, basalt fiber was laid between them, and they were placed on the studs installed in the rotor (Fig. 4).

Figure 2. Selected grid view.

a = 1,2 мм, δ = 0,25 мм.

The support grids for laying along the rotor diameter have a length of L_c = 700 mm, a diameter of D = 300 mm, and a surface area of S = 0.66 m^2.

Fig. 3. View of basalt fiber mat rotor filter.

(weight of basalt fiber m = 100 grams)

A rotor-filter with a basalt fiber mat was installed in the apparatus. (Figure 4).

Figure 4. Basalt fiber rotor-filter installed in the apparatus.

Experimental studies were conducted in an experimental setup to determine the resistance coefficients of basalt fiber filters (Figure 5).

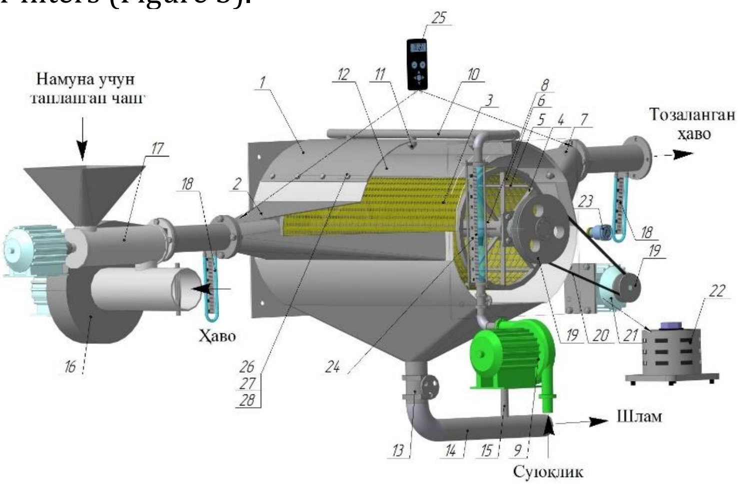

Figure 5. Overview of the device.

1 – device body; 2 – diffuser; 3 - basalt fiber rotor filter; 5 - stern; 6 – steel mesh; 7 – confusor; 8 – shaft; 9 – pump; 10 – liquid pipe; 11 – nozzle; 12 – umbrella; 13 – fist; 14 – slurry pipeline; 15 – level adjusting pipe; 16 – fan; 17 – screw feeder; 18 – Prandl tube; 19 – pulley; 20 – belt; 21 – electric motor; 22 – LATR; 23 – tachometer; 24 – rotometer; 25 – electron monometer **JM-510** ; 26,27,28 – bolt, nut and washer.

The minimum speed, flow rate, and resistance coefficients of the working parts of the device, fan 16 (efficiency $Q_{мах}$ =350 m^3/h; electric motor power N_{dv}=0.7 *kW*; rotation frequency *n*=1200 *revol/min*) of the centrifugal type, Pitot-Prandall tube 18 (50 and 100 mm in size). A metal tube with *D* =60 *mm*, and *L* =1000 *mm*, determines the dust gas velocity. The tube contains 2 Pitot-Prandall tubes with an internal diameter of 7 *mm*, which determine the static and dynamic pressures. The Pitot-Prandall tube was selected by the diameter of the fan outlet pipe according to the requirements for determining the gas velocity, efficiency, and pressure St. In addition, to compare the results obtained, an electronic gas velocity measuring device with a digital display (25) was used to determine the gas velocity ANEMOMETER **VA06 - TROTEC** (Measurement range 1.1÷50 m/s, error coefficient 0.2%, when the gas velocity exceeds 50 *m/s*, the error coefficient is up to 5%). To control the gas velocity, a damper was installed on the suction pipe of the fan, forming an angle of 0^0;30^0;45^0;60^0;90^0.

Researchers I.T. Karimov and A.S. Isomiddinov determined the resistance coefficients of the confusor and diffuser of the rotor filter device and the resistance coefficients of the base grids [4], which are presented in the following table.

Table **1**
The resistance coefficient of the diffuser values

υ_{gas}, m/s	7	14	21	28	35
$\xi_{difference}$	0.31	0.3	0.31	0.308	0.32

Table **2**
The resistance coefficient of the confusor values

υ_{gas}, m/s	7	14	21	28	35
ξ_{conf}	0.22	0.20	0.21	0.2	0.2

The coefficient of resistance of the confusor $\xi_{конф}$=0,2 and the coefficient of resistance of the diffuser $\xi_{диф}$ =0,3 were taken. As a result of similar experimental studies, the raw resistance coefficients of the base grid were determined, and at the above gas velocities, $\xi_{таянч}$=0,2 [4].
In general, the total local resistance of the device without a basalt fiber rotor filter is equal to the sum of the resistance coefficients of the confusor, diffuser and base mesh.

$$\xi_1 = \xi_{conf} + \xi_{difference} + x_{base} = 0.2+0.3+0.2=0.7$$

Experimental studies were focused on determining the resistance coefficients of rotors covered with basalt fibers of 3 different weights.

The experiments were focused on determining the resistance coefficient of basalt fiber rotor filters in the absence of liquid supply to the device and gas velocity to the apparatus $\upsilon_г$ = 7÷35 m/s was increased in steps of 7 m/s. In the experiments, the rotor rotation frequency was set at an average value of n=15 *revol/min*, and the gas density was set at $\rho_г$=1,29 kg/m^3 (for air). In each experiment, the gas velocities entering and leaving the apparatus were determined using a BA06-TROTEC electronic anemometer, and the resistance coefficients of the basalt fiber rotor filter were determined from the difference in gas velocities for each mode.

During the experimental determination of the resistance coefficient of the fiber contact element of the device, the effect of the rotation frequency of the rotor filter on the gas flow was not noticed. Therefore, the frequency of rotation of the rotor was not taken into account in the experimental determination of the resistance coefficients of the device.

The obtained experimental results are presented in Table 3.

Table 3
Experimental results were obtained in the determination of resistance coefficients of the basalt fiber filter of the apparatus in the case of no liquid supply.

N	Basalt fiber mass m, kg	Comparative contact surface S, m^2	Rotor filter surface area S_p, m^2	The speed of the gas entering the apparatus $V_{g, m/s}$	Velocity of the gas at the exit of the apparatus $V_{g, m/s}$	Total resistance coefficient enti ξ_{mind}	Basalt fiber coefficient of friction ξ_b	Correction factor ΔK
1.	0.1	17	0.66	7	3.3	2.1	1.4	0.054
2.				14	6.7	2.08		
3.				21	10	2.1		
4.				28	13	2.15		

5.				35	17	2.05		
The average value of the resistance coefficient						2.1		
1				7	2.3	3		
2				14	4.5	3.1		
3	0.15	25.5	0.66	21	7	3	3	0.059
4				28	9.5	2.95		
5				35	12	2.92		
The average value of the resistance coefficient						3		
1				7	1.75	4		
2				14	3.4	4.1		
3	0.2	34	0.66	21	5.2	4.04		0.064
4				28	7	4		
5				35	9	3.9		
The average value of the resistance coefficient						4		

The values of the resistance coefficients given in Table 3 are the total resistance coefficient in the case where the baffle and diffuser and the resistance coefficients of the base grids are added. From the values of these total resistance coefficients, we subtract the resistance coefficients of the confusion and diffuser and the base grids and determine the resistance coefficient of the basalt fiber filter.

The mass of basalt fiber is m = 100 grams;

$$\xi_б = \xi_{ум} - \xi_1 = 2{,}1 - 0{,}7 = 1{,}4$$

The mass of basalt fiber is m = 150 grams;

$$\xi_б = \xi_{ум} - \xi_1 = 3 - 0{,}7 = 2{,}3$$

The mass of basalt fiber is m = 200 grams;

$$\xi_б = \xi_{ум} - \xi_1 = 4 - 0{,}7 = 3{,}3$$

The resistance coefficients and the total resistance coefficients depend on the relative contact surfaces of the basalt fibers in the case that no liquid was supplied to the rotor- filter graphs were built. (Figure 10).

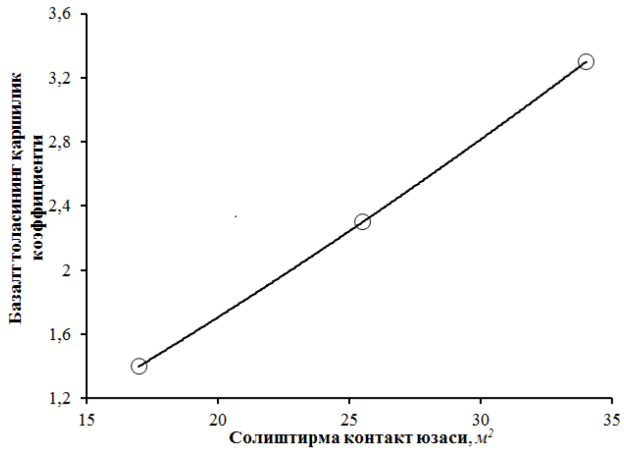

Figure 7. Variation of the resistance coefficient depending on the relative contact surfaces of the basalt fiber rotor filter schedule.

The resulting regression equation looks like this.

$$y = 0.0007x^2 + 0.0765x - 0.1 \qquad R^2 = 0.9985 \qquad (4)$$

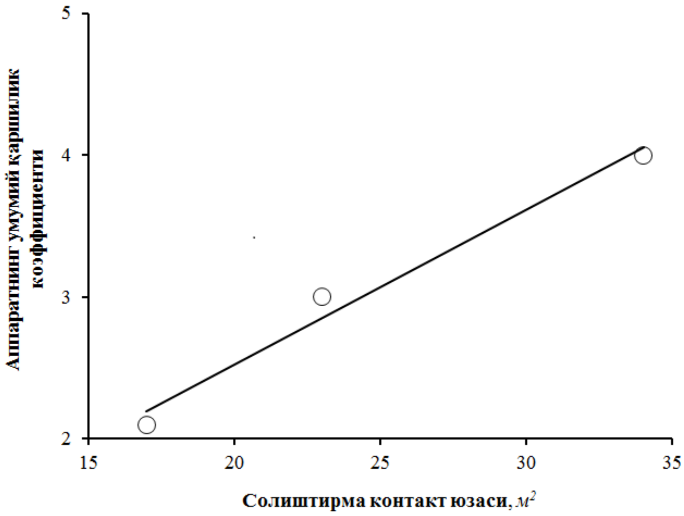

Fig. 8. Basalt fiber rotor depending on the relative contact surfaces of the filter change the total resistance coefficient graph (in the case where local and base grid resistance coefficients are added.)

y = 0.1092x + 0.3399 R^2 = 0.9811 (5)

Based on the experimental studies, the following empirical equation was obtained for determining the resistance coefficient of the basalt fiber rotor filter [].

$$\xi_\phi = \Delta K \frac{S_\phi}{S_c} \quad (6)$$

where Δ K is the correction factor, which is determined by the following equation .

$$\Delta \mathrm{K} = \frac{\xi_T}{\xi_н} \quad (7)$$

where $\xi_т$ is the resistance coefficient of the rotor filter determined by experiments; ξ_n is the relative resistance coefficient of the rotor filter, which is determined as follows.

$$\xi_н = \frac{S_\phi}{S_c} \quad (8)$$

where S_f is the relative contact surface area of the basalt fiber filter by mass, these values were determined above, m^2 ; S_c is the total surface area of the support grid on which the basalt fibers are laid, S_t = 0.66 m^2.

Using equation (8), we determine the relative resistance coefficients of the rotor filter. From Table 3 above, the relative contact surface of basalt fibers weighing 100 grams is S_f =17 m^2. In this case, it is equal to:

$$\xi_н = \frac{S_\phi}{S_\mathrm{T}} = \frac{17}{0,66} = 25,7$$

We determine the values of the correction coefficients using equation (8).

$$\Delta \mathrm{K} = \frac{\xi_T}{\xi_н} = \frac{1,4}{25,7} = 0,054$$

of S_f = 25.5 and 34 m^2 laid on the rotor were also determined using the same method. The calculations and experimental results are presented in Table 3.

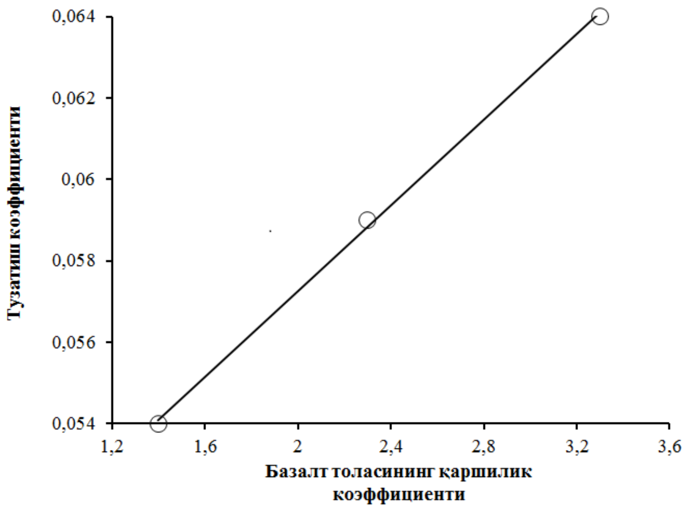

Figure 11. A graph of the variation of the correction coefficient depending on the resistance coefficients of the basalt fiber rotor filter.

$$y = 0.0053x + 0.0467 \qquad R^2 = 0.9991 \qquad (9)$$

Using the recommended empirical equation, theoretical values of the resistance coefficients were determined and compared with experimental values. The error between them was Δ = ±4%.

Conclusion

In this scientific research work, resistance coefficients were determined experimentally, depending on the relative contact surfaces of the local and base grids and the basalt fibers laid on the rotor filter in the state where the liquid is not supplied to the rotor filter device that cleans dusty gases and gas mixtures in a wet method. As a result, it was possible to determine the liquid consumption and energy consumption for optimal values of resistance coefficients and cleaning efficiency by supplying liquid to the device.

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