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DETERMINATION OF ACCEPTABLE PARAMETERS OF CLEANING EFFICIENCY OF A ROTOR-FILTER DEVICE EQUIPPED WITH A SURFACE CONTACT ELEMENT

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Abstract

In this article, we studied the impact of various parameters of the rotor-filter apparatus surface contact element on its cleaning efficiency for dust gas. The experiment included variables such as the diameter of the liquid nozzle (d_{sh}=2mm), fluid consumption (Q_{liquid}=0.071-0.272 m^3/hr), filter hole diameter (d_f=3mm), and the angle of installation of the contact element on the rotor (α=30°, 45°, and 60°). The number of contact elements varied depending on the installation angle: 12 for 30° and 60° and 8 or 6 pieces for 45°. Additionally, gas speed (υ_g=5-25 m/s) and gas density for a mixture of air and dolomite dust (ρ_g=1.89 kg/m^3 and 360.3 mg/m^3) were selected.

The results showed that the cleaning efficiency of dust particles up to 1-5 μm and 5-20 μm can be increased by 23.45% and 3.05%, respectively, compared to the existing structure.

Keywords: Hydraulic resistance, liquid consumption, liquid film layer, surface contact element, rotor filter, mass exchange, and cleaning efficiency.

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Introduction:
It is urgent to increase the contact surfaces in dust gas scrubbers and thereby justify the optimal parameters of hydraulic resistance, cleaning efficiency and energy consumption. Therefore, most of the scientific research work carried out in this field is to increase the contact elements of the surface of the device, to create a simple structure of the element, to organize hydrodynamic and mass processing processes. From previous research results, it is known that simplifying the design of the surface contact element reduces the hydraulic resistance in the device, but harms the cleaning efficiency of the device.
In addition, it increases the output of liquid droplets from the device along with the purified gas. This, in turn, increases the level of accumulation of dust particles in the pipes of the device.
Taking into account the information given above, the constructive scheme of the rotor-filter device was developed [1], and the existing device belongs to the technique of cleaning dusty gases generated in the chemical industry and construction materials production enterprises.
The device consists of a rotating rotor and a filter string material covered on its upper part, a diffuser oriented perpendicular to the surface of the string material for filtering dusty gases, a nozzle that scatters the liquid in the ejection method, a screen that spreads the liquid flat on the surface of the filter, a cylindrical body equipped with a bath where the working fluid is collected and a sludge discharge pipe, and purified air. consists of a confusor that discharges into the atmosphere. When the dusty gas flow moves through the diffuser and hits the filter surface perpendicularly, the liquid film formed on the working surface of the filter is cleaned of dust particles. The purified gas is released into the atmosphere through the condenser.
In the conducted research work [2,3,4], the effect of hydraulic resistance of the device on cleaning efficiency and energy consumption was organized. A rotating rotor in the form of a cylinder was used as a contact element. The upper part of the rotor is covered with porosity material as a filter and small diameter holes are opened [2,5,6]. Based on the conducted research, the optimal parameters of the device are based, and mathematical connections are obtained.

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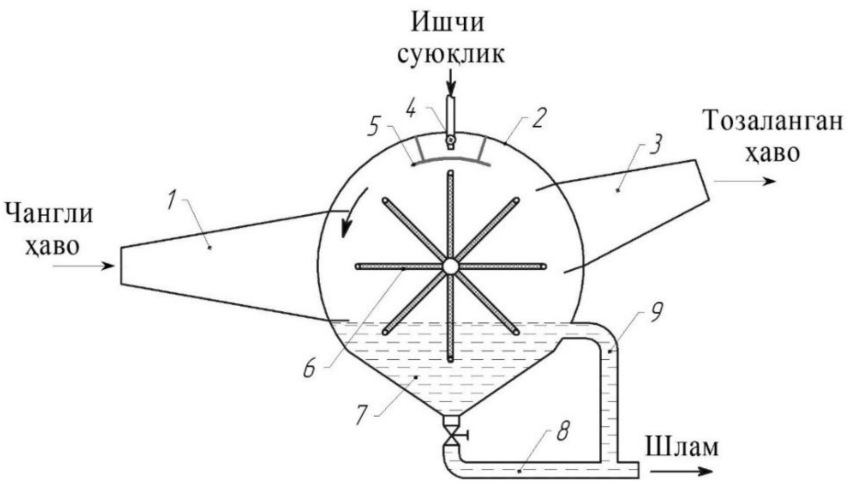
However, in the rotor-filter device, the patterns of changes in the device's hydraulic resistance, cleaning efficiency, and energy consumption are not organized in different designs of surface contact elements.

Research object:
Based on the above, a new design scheme for the surface contact element to be installed on the rotor of the device was developed. The advantage of the surface contact element over the surface contact elements of existing dust gas cleaning devices is that, firstly, its working surface is quickly changed and provides an increase in the contact surface of the filter. Secondly, the installation of filtering grids on the shaft at a certain degree of inclination makes it possible to completely cover the gas flow on the working surface. The device equipped with the surface contact element of the new design and the general view of the surface contact element are presented in Figures 1 and 2. Experimental studies were conducted in two stages.



1 diffuser; 2 cylindrical bodies; 3 confusors; 4 working fluid nozzles; 5 probes; 6 surface contact elements; 7 liquid baths; 8 slurry pipes; 9 straightening pipe.

Figure 1. Scheme of the device equipped with a surface contact element.

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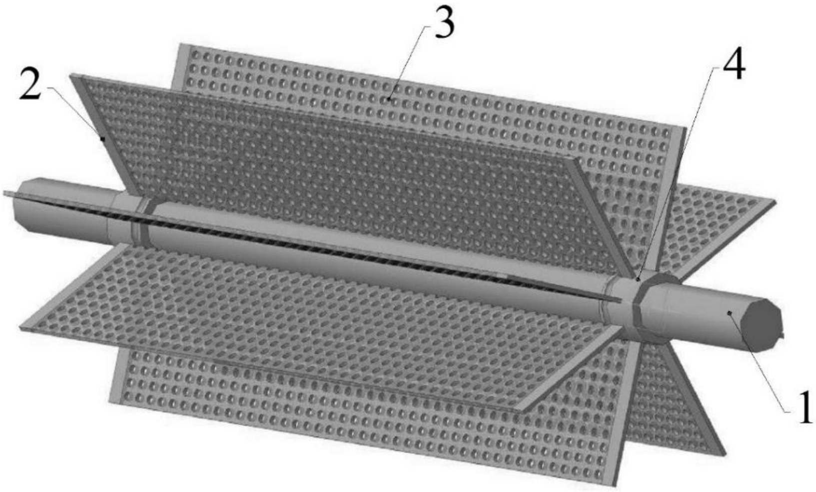

1st shaft; 2nd pole rod; 3rd filter; 4th connecting rod.

Figure 2. Overview of the surface contact element.

Research results

At the first stage, the hydraulic resistance of the device was determined for various parameters of the surface contact element. The study of hydraulic resistance in the following limits of variable factors, the diameter of the liquid nozzle d_{sh}=2 mm, *fluid consumption* Q_l=0,071÷0,272 m^3/hour the intermediate step increased to 0.060 m3/h, the diameter of the filter hole d_f=3 mm, the angle of installation of the contact element on the rotor α= 30º; The number of 45° and 60° contact elements is 12, corresponding to the installation angle; 8 and 6 pieces, gas speed υ_g=5÷The intermediate step up to 25 m/s was increased by 5 m/s. In the experiments, the frequency of revolutions of the rotor was set at an average value of n=25 rev/min, the gas density for air ρ_g=1,29 kg/m^3 and for a mixture of air and dolomite dust ρ_g=1,89 kg/m^3 (in which dolomite dust in 1 m^3 of air was set at 36º.3 mg/m^3 according to PDK requirement and GOST-23672-79.

Taking into account the influence of the external environment during the experiments, the temperature for the water and gas system was set at 20ºC±2. Based on the results of the experiment, comparison graphs were built on the dependence of hydraulic resistance on fluid consumption. (Figures 3; 4 and 5).

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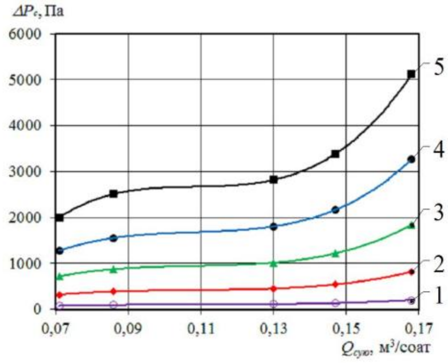
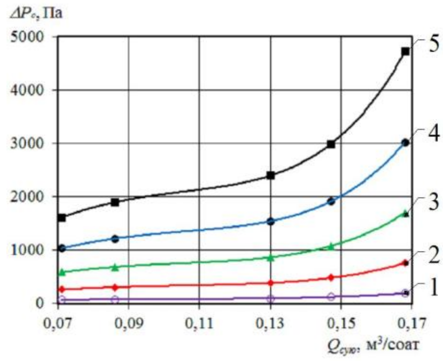


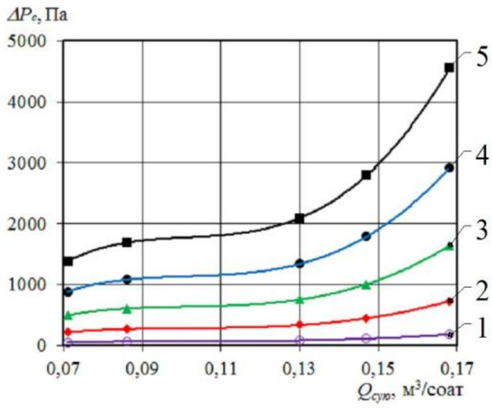
1 – υ_g=5 m/s; 1 – υ_g=10 m/s; 1 – υ_g=15 m/s; 1 – υ_g=20 m/s; 1 – υ_g=25 m/s.

Figure-3. α= 30° **and hydraulic resistance at** ρ_g=1,89 kg/m^3 *;* **fluid consumption of** ΔP_s **depending on** Q_l



1 – υ_g=5 m/s; 1 – υ_g=10 m/s; 1 – υ_g=15 m/s; 1 – υ_g=20 m/s; 1 – υ_g=25 m/s.

Figure-4. α= 45°**and** *hydraulic resistance at* ρ_g=1,89 kg/m^3 ΔP_s dependence of fluid consumption on Ql



1 – υ_g=5 m/s; 1 – υ_g=10 m/s; 1 – υ_g=15 m/s; 1 – υ_g=20 m/s; 1 – υ_g=25 m/s.

Figure-5. α= 60°**and** *hydraulic resistance at* ρ_g=1,89 kg/m^3 ΔP_s dependence of fluid consumption on Ql

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From the comparison graphs in Figures 3 , 4 and 5, it can be seen that the gas density ρ_g=1,29 kg/m^3, fluid consumption Q_l=0,071÷0,168 m^3/hour an intermediate step 0,060 m^3/hour, υ_g=5÷25 m/s intermediate step to 5 m/s as increases with and *the angle of installation of the surface contact element on the rotor* hydraulic resistance at α=60^o ; from ΔP=55,3 Pa to ΔP_s=4555 Pa , the angle of installation of the surface contact element on the rotor hydraulic resistance at α=45^o from ΔP=64,5 Pa to ΔP_s=4716 Pa the angle of installation of the surface contact element on the rotor hydraulic resistance at α=30^o from ΔP=80 Pa to ΔP_s=5116 Pa increase was observed. Gas density ρ_g=1,89 kg/m^3 and at is the angle of installation of the contact element on the rotor hydraulic resistance at α=60^o from ΔP=81 Pa to ΔP_s=6674 Pa , the angle of installation of the surface contact element on the rotor hydraulic resistance at α=45^o from ΔP=94,5 Pa to ΔP_s=6910 Pa and the angle of installation of the surface contact element on the rotor hydraulic resistance at α=30^o fromΔP=117 Pa to ΔP_s=7500 Pa increase was observed.

This situation can be explained by the thickening of the liquid film layer formed on the surface of the contact element with increasing liquid consumption, as a result of which the resistance of the contact element increases. In addition, the increase in the density of the gas and dust mixture has a significant effect on the hydraulic resistance. Therefore, in researching the cleaning efficiency of the device, it is necessary to take into account the type of dust, its physical and chemical properties, the requirement of PDK, and the density of the gas and dust mixture.

Using the method of least squares to the graphical relationships presented in Figures3, 4 and 5 (gas density r_g=1.89 kg/m^3 and liquid consumption Q_s=0.071÷0.168 m^3/h when the intermediate step increases by 0.060 m^3/h) the following empirical formulas were obtained [2,13,14];

When the angle of installation of the contact element on the rotor is α= 30° and the number of elements is 12 pieces.

υ_g=5 m/s, y = 18805x2 - 3366,6x + 233,66 R^2 = 0,9560 (1)

υ_g=10 m/s, y = 75390x2 - 13507x + 936,76 R^2 = 0,9559 (2)

υ_g=15 m/s, y = 169750x2 - 30417x + 2109 R^2 = 0,9559 (3)

υ_g=20 m/s , y = 301553x2 - 54016x + 3745,3 R^2 = 0,9559 (4)

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υ_g=25 m/s , y = 464987x2 - 83369x + 5842,5 R^2 = 0,9446 (5)

When the angle of installation of the contact element on the rotor is α= 45° and the number of elements is 8.

υ_g=5 m/s, y = 19680x2 - 3548,8x + 224,56 R^2 = 0,9734 (6)
υ_g=10 m/s, y = 79085x2 - 14293x + 903,72 R^2 = 0,9719 (7)
υ_g=15 m/s, y = 177793x2 - 32120x + 2031,4 R^2 = 0,9719 (8)
υ_g=20 m/s, y = 313574x2 - 56509x + 3580,8 R^2 = 0,9718 (9)
υ_g=25 m/s , y = 493622x2 - 89164x + 5639,3 R^2 = 0,9719 (10)

When the angle of installation of the contact element on the rotor is α= 60° and the number of elements is 6.

υ_g=5 m/s, y = 21218x2 - 3897,3x + 233,32 R^2 = 0,9706 (11)
υ_g=10 m/s, y = 84722x2 - 15550x + 931,23 R^2 = 0,9707 (12)
υ_g=15 m/s, y = 190553x2 - 34971x + 2094,1 R^2 = 0,9705 (13)
υ_g=20 m/s, y = 338856x2 - 62209x + 3726,2 R^2 = 0,9706 (14)
υ_g=25 m/s, y = 529680x2 - 97253x + 5824,8 R^2 = 0,9706 (15)

In the second stage, the influence of the hydraulic resistance of the device on the cleaning efficiency was studied. The results of the experiment on determining the hydraulic resistance and the research work of K. T. Semrau [2,7] were used in the research of the cleaning efficiency of the device. It is known from the research work of K. T. Semrau that the cleaning efficiency depends on the hydraulic resistance of the device and does not depend on the size and construction of the device. In this case, the total energy consumption should be spent on the cleaning of dusty gases with the help of liquids. Based on the above, the effect of the hydraulic resistance of the structure on the cleaning efficiency was studied. In the experiments, the following limits of the variable factors, the diameter of the liquid nozzle d_{sh}=2 mm[8,9,10,11,12], liquid consumption Q_s=0.071÷0.272 m³/h, the intermediate step increased by 0.060 m³/h, the diameter of the filter hole d_f=3 mm, the angle of installation of the contact element on the rotor α= 30°; The number of 45° and 60° contact elements is 12, corresponding to the installation angle; 8 and 6 pieces, gas speed y υ_g=5÷25 m/s, the intermediate step was increased by 5 m/s. In the experiments, the frequency of revolutions of the rotor

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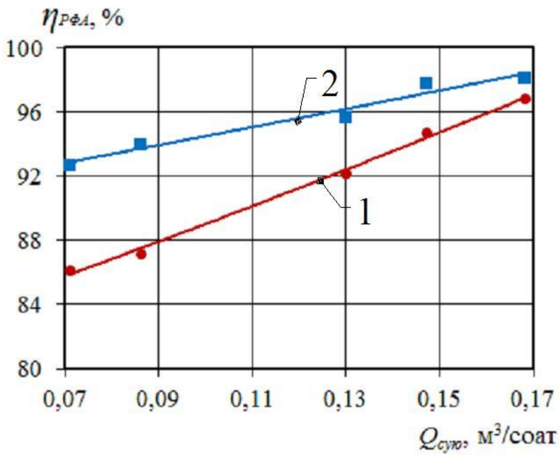
at an average value of n=25 rev/min, the gas density r_g=1.89 kg/m³ for a mixture of air and dolomite dust (in which 1 m³ of air contains dolomite dust is required by PDK and 360according to GOST-23672-79.3 mg/m³) was determined. Taking into account the influence of the external environment during the experiments, the temperature for the water and gas system was set at 20°C±2. Based on the obtained experimental results, comparison graphs were constructed on the effect of hydraulic resistance on cleaning efficiency. (Figures 6; 7 and 8). Taking into account the multifactorial nature of the experiments, graphs were constructed for lower and higher gas velocity loads.

From the data given in Figures 6, 7 and 8, it can be seen that when the angle of installation of the contact element on the rotor is α= 60° and the number of elements is 6, the cleaning efficiency at the lower limit of the gas speed is 86.17÷96 up to .81%, 92.71÷98.14% at high load of gas speed, when the installation angle of the contact element is α= 45° and the number of elements is 8, the cleaning efficiency at the lower limit of the gas speed is Q_s=0.071÷0.071÷ 93.28÷97.19% in intervals of 0.272 m³/h, 96.4÷99.75% at high load of gas speed and at the lower limit of gas speed when the angle of installation of the contact element is α= 60° and the number of elements is 6 pieces cleaning efficiency was up to 86.17÷96.81% in the intervals of Q_s=0.071÷0.272 m³/h, and 92.71÷98.14% at high gas speed loading. Intermediate growth did not exceed 15%.



1- the installation angle of the contact element on the rotor a= 60°, gas velocity υ_g=5 m/s, liquid consumption Qliquid=0.071÷0.272 m³/hour; gas velocity, angle of installation of the contact element on the 2nd rotor α= 60°, υ_g=25 m/s, liquid consumption Qs=0.071÷0.272 m³/h ;

Figure 6. Dependence of cleaning efficiency ηRFA on liquid consumption Ql

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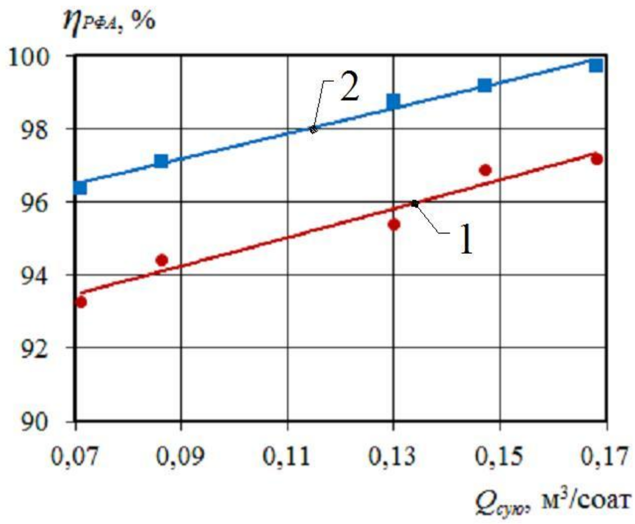
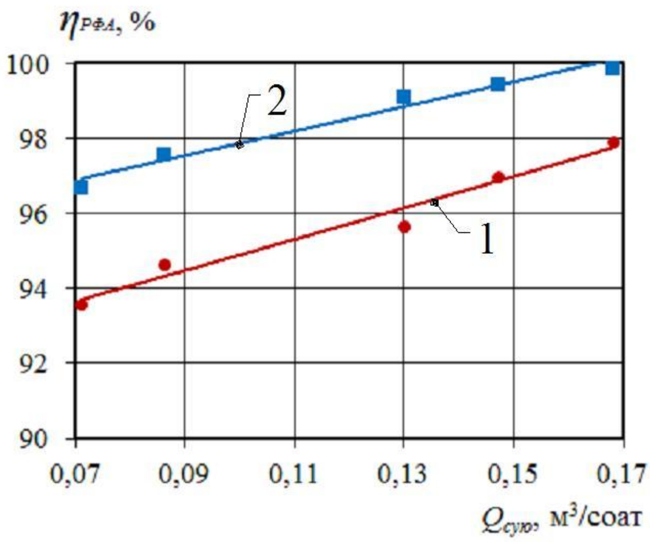


1- the angle of installation of the contact element on the rotor α= 45°, gas velocity υ_g=5 m/s, fluid consumption Q_s=0,071÷0,272 m^3/s; gas velocity 2- the angle of installation of the contact element on the rotor α= 45°, υ_g=25 m/s, fluid consumption Q_s=0,071÷0,272 m^3/s;

Figure 7. Dependence of cleaning efficiency ηRFA on liquid consumption Q_l



1- the angle of installation of the contact element on the rotor α= 30°, gas velocity υ_g=5 m/s, liquid consumption Ql=0.071÷0.272 m^3/hour; gas speed 2- angle of installation of the contact element on the rotor α= 30°, υg=25 m/s, liquid consumption Ql=0.071÷0.272 m^3/h;

Figure 8. Dependence of cleaning efficiency ηRFA on liquid consumption Ql

The results of the experiment show that the expansion of the angle of installation of the contact element on the rotor reduces the pressure lost in the

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device, but has a negative effect on the cleaning efficiency. On the contrary, narrowing the angle of installation of the contact element on the rotor increases the number of elements, which in turn determines the increase of the contact surface and the improvement of cleaning efficiency. One of the technical requirements for this type of devices is to increase the contact surfaces with low energy consumption and thereby improve the cleaning efficiency.

Using the method of least squares, the following empirical formulas were obtained for the graphic dependences presented in Figures 7 and 8 [2,13,14];

When the angle of installation of the surface contact element on the rotor is α= 60°;

υ_g=5 m/s, $y = 78{,}632e^{1{,}2404x}$ $R^2 = 0{,}9957$ (16)

υ_g=25 m/s, $y = 89{,}036e^{0{,}5931x}$ $R^2 = 0{,}9635$ (17)

When the angle of installation of the surface contact element on the rotor is α= 45°;

υ_g=5 m/s, $y = 90{,}823e^{0{,}4114x}$ $R^2 = 0{,}9535$ (18)

υ_g=25 m/s, $y = 94{,}137e^{0{,}3531x}$ $R^2 = 0{,}9906$ (19)

When the angle of installation of the surface contact element on the rotor is α= 30°;

υ_g=5 m/s, $y = 90{,}842e^{0{,}4359x}$ $R^2 = 0{,}9663$ (20)

υ_g=25 m/s, $y = 94{,}667e^{0{,}3319x}$ $R^2 = 0{,}9708$ (21)

The following values were adopted as optimal parameters in the experimental studies conducted in order to use different constructions of the surface contact element of the rotor-filter device and to evaluate its effect on the device's hydraulic resistance and cleaning efficiency. Mathematical planning method and PLANEX program were used for taking values [15,16].

- the diameter of the surface contact element filter hole d_f=3 mm;
- the diameter of the nozzle hole d_{sh}=2 mm;
- the amount of liquid used to clean 1m³ of air from dust particles Q_s=0.04m³/l;
- velocity of gas supplied to the device y_g=25 m/s;
-hydraulic resistance of the device DPs=2.7kPa;
-cleaning efficiency of the device η_{RFA}=99.45%

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Summary:

- the coefficient of resistance of the working bodies of the structure was determined in different constructions of the surface contact elements of the structure;
- the hydraulic resistance of the structure at different values of the resistance coefficient and, depending on it, the cleaning efficiency were determined;
- the results obtained in the rotor-filter system showed that compared to the existing system, it is possible to achieve a higher efficiency in cleaning dust particles up to 1÷5 μm by 23.45% and in cleaning dust particles up to 5÷20 μm by 3.05%.

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