

STUDY OF THE HYDRODYNAMICS OF TWO-PHASE CIRCULATING FLOWS IN A PILE DUST COLLECTOR

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<https://doi.org/10.5281/zenodo.10029705>

Abstract. Today, rapid development of production processes is observed worldwide. The ever-expanding scale of human activities in nature, the involvement of a large amount of raw materials, water and energy resources in production processes have a significant impact on the environment. Accordingly, protecting the environment from pollution is becoming one of the priority tasks of today. The fundamental solution to the problem of protecting the air basin from industrial pollution is to create waste-free technologies.

Keywords. Dust, clump, vacuum cleaner, device, Venturi tube, Stokes number, velocity, liquid, clump, gas volume, gas bubbles, clump layer, angular velocity, purification, technological process, functional scheme, efficiency, analytical relationships, comparison.

In recent years, in our republic, in addition to environmental protection measures, the improvement of dust cleaning systems and the creation of technologies that ensure the increase in the productivity of raw materials for production or further processing, thereby increasing the economy of production, certain results have been achieved. Development of constructions of dust collectors is one of the urgent tasks of modern science and technology.

Currently, the improvement of dust cleaning devices is of great importance in order to prevent the emission of a large amount of gas emissions into the atmosphere, which causes environmental pollution in the main part of the technological processes in production enterprises.

In this regard, we set ourselves the goal of improving the devices for cleaning dust gases coming out of production enterprises.

Several experiments were conducted by us on the device of a pile vacuum cleaner, that is, the hydrodynamics of the interaction of two-phase circulating flows was studied. In it, the interaction of the geometric dimensions of the device with the flow of gas particles and water droplets was determined. A model of the device was created in Matlab and Solidworks programs to verify the optimal values of the device's structural dimensions with those of the mathematical model.

The dust removal efficiency of the pile dust collector can be up to 99%, one of the factors that can negatively affect the efficiency is the increase of dust in the device (should be from 1 to 500 g/m³).

The structural dimensions of the pile dust cleaning device were determined by the consumption of the gas entering the device, and its diameter can be calculated as follows [1]:

$$D_a = \left(\frac{4V_z}{\pi v_z} \right)^{1/2} \quad (1)$$

where V_e - consumption of gas entering the device, m³/s; v_e speed of gas entering the device, m/s.

The maximum diameter of gas particles that can be cleaned in a dust cleaning device can be determined by the following formula:

$$d_s = \left(\frac{\frac{v_e \cdot \ln \frac{D_a}{D_{ex}}}{H_a}}{\frac{1}{18\mu_e} \cdot (\rho_m - \rho_e) \cdot \omega^2} \right)^{1/2} \quad (2)$$

where D_{ex} - the diameter of the inlet of gas particles to the device, m; H_a - the height of the gas cleaning part of the device, m; ω - angular speed of gas particles in the device, 1/s.

The main criterion for evaluating the performance of a stack dust cleaning device is the dust cleaning efficiency, and it is calculated by the ratio of gas particles cleaned in the device and entering the device as follows[2]:

$$\eta = \frac{q_6 - q_o}{q_6} \cdot 100 \quad (3)$$

where q_6 - initial dusting of gas particles, g/m³; q_o -- dustiness of gas particles at the exit, g/m³.

Gas particles can be supplied to the dust treatment device through 4 inlets Figure 1, where the overall efficiency of the device is as follows[3]:

$$\eta_{ym} = \frac{V_1\eta_1 + V_2\eta_2 + V_3\eta_3 + V_4\eta_4}{V} \quad (4)$$

where $\eta_1, \eta_2, \eta_3, \eta_4$ - dust removal efficiencies in the first, second, third and fourth streams.

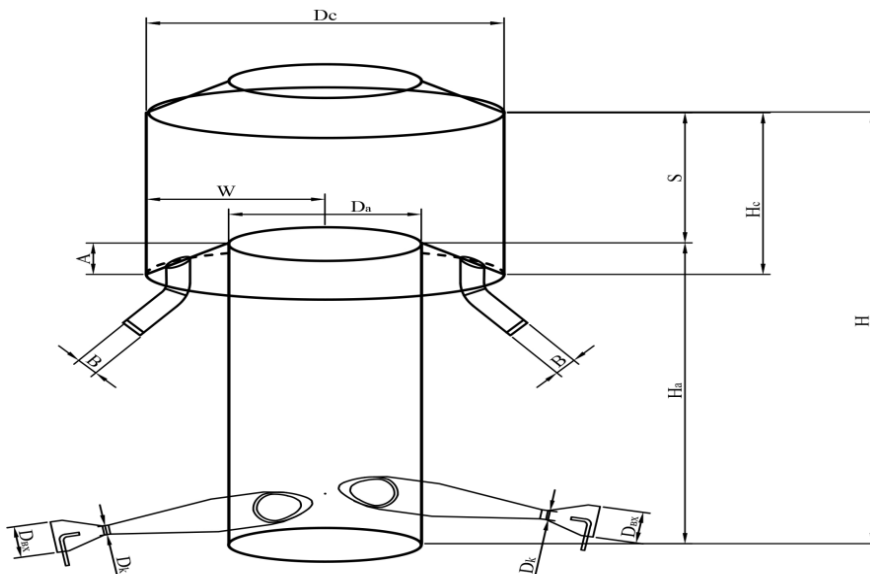
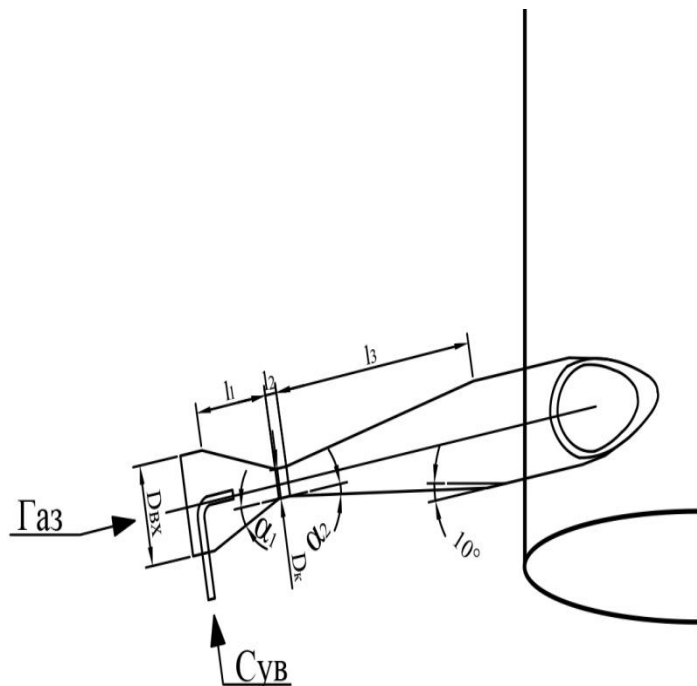


Figure 1. A compact vacuum cleaner

In the dust cleaning device, water and gas particles enter the main part of the device through the pipe at an angle of 10° , which further increases the formation of clumps. The taper angle of the baffle in the inlet pipe is 20° , and the angle of the diffuser is 6° Fig. 2.

**Figure 2. Dimensions of the inlet pipe in a pile dust collector**

The main geometric dimensions of the vacuum cleaner device were determined by calculations, and the dimensions of the structure were calculated for the process of dust removal during the production of ordinary superphosphate fertilizer. The calculated dimensions of the device are listed in the following table:

These dimensions are the parameters that mainly affect the dust removal efficiency of the structure, and by changing them, the efficiency index can also be changed.

Table 1**Structural dimensions of the dust cleaning device**

Parameters	Value, mm
D_c	600
W	300
D_a	250
A	120
B	180
S	400
H_c	520
H_a	1600
H	2000
D_{BX}	115

D_k	70
L_{BEHT}	580

A Venturi tube is installed at the inlets of this device, and through dropwise transmission (fogging) water is absorbed by dust particles and rises to the separator by forming a lump, and the dust particles are discharged into the hopper and the purified gases are released into the atmosphere.

Thus, by calculating the amount of water and gas used for cleaning gases in a dust cleaning device, its efficiency indicators can be determined. For this, the diameter of gas particles moving in the device is expressed as d_3 and the diameter of water particles as d_2 , and only when the condition $d_3 < d_2$ is fulfilled, the device will clean dust. In addition, we assume that liquid and gas particles are incompressible, non-deformable and non-evaporating.

In the literature, there are many dependences of the Stokes number on the efficiency of dust collectors. But in these researches, the result $\eta = \eta(\text{Stk}_{32})$ was obtained by expressing the structure of the flow through certain hypotheses. Therefore, it is appropriate to calculate these values separately for each device, because the dependence of the efficiency on the Stokes number for high dusting at the inlet of the device has not been studied in the literature.

In Figure 3, even when we increase the flow of gas particles and water droplets entering the device, the efficiency does not decrease significantly (3%). It should be noted that the calculated values (curve 1) were in good agreement with the experimental values (curve 2)

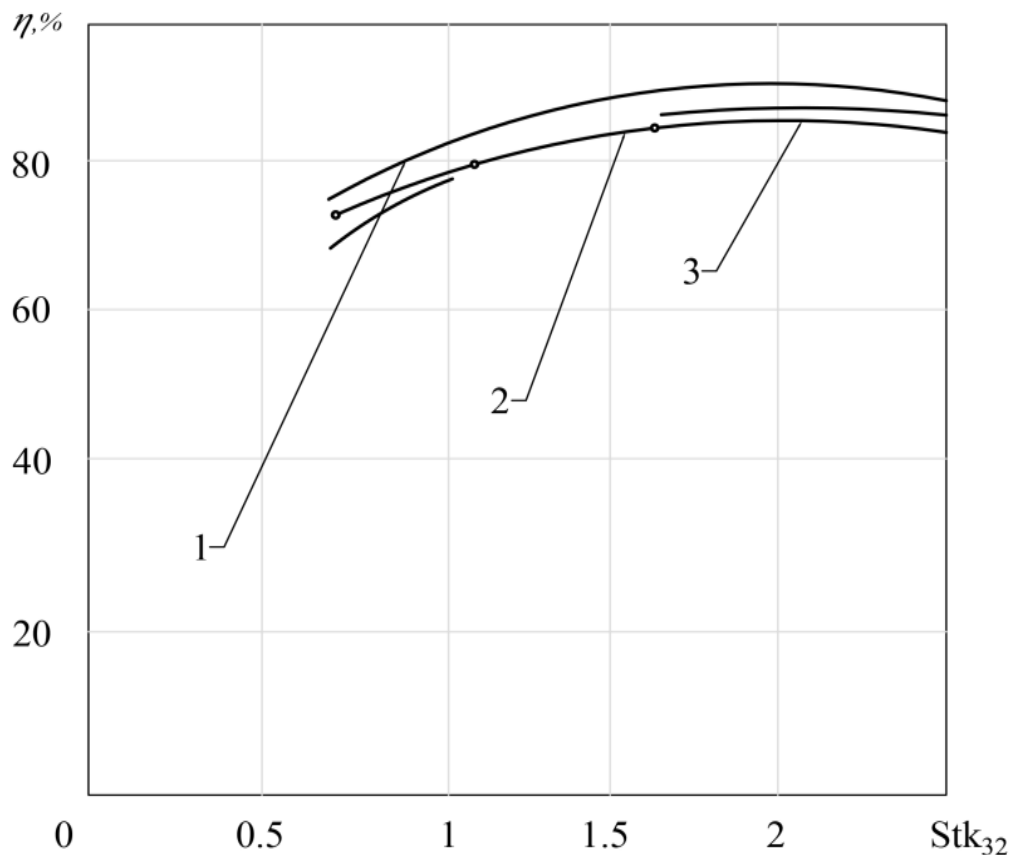


Figure 3. Dependence of the dust removal efficiency on the Stokes number

Table 2 compares how well the data calculated by mathematical modeling correspond to the experimental data.

Table 2

Absolute error of calculated and experimental data

Gas consumption	Water consumption	Efficiency (experimental)	Efficiency (calculated)	Absolute error
m^3/s	m^3/h	$\eta_{\text{экс}}, \%$	$\eta_{\text{хис}}, \%$	$\Delta \eta, \%$
1,54	4,27	94,2	94,86	0,66
1,54	4,27	94,3	95,37	1,07
1,84	4,96	95,3	97,59	2,29
1,84	4,96	98,5	99,8	1,27
2,02	5,45	96,3	97,45	1,156
2,02	5,45	97,4	98,3	0,9

Table 2 shows that the maximum absolute error of the calculated and experimental data did not exceed 2.29%.

When the gas reaches a certain speed in the narrow part of the dust cleaning channel with lumps, the liquid in the device begins to form lumps. 0.5 mm is formed in the lower lumpy layer with high gas volume and less gas bubbles, and the angular velocities of the lower layer are 1.4-1.8 times higher than the angular velocities of the upper layer.

The use of a functional scheme in the technological process of heaped dust cleaning allows to increase the efficiency by 98.7%.

Comparison of the results of calculations on the obtained analytical dependences and the results of their experimental research on similar constructions and operating modes of dust cleaning devices of other authors was found to be in high agreement and the efficiency of the created drum vacuum cleaner device is higher.

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