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SELECTION OF THE RANGE OF VARIABLE PARAMETERS IN A FRUCTOCONE DEVICE BASED ON VISUAL EVALUATION IN MATLAB ENVIRONMENT

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A B S T R A C T	K E Y W O R D S
The article develops a methodology for determining the range of variable parameters for planning experiments in a wet dust collector comprising a water spray nozzle, a truncated-cone flow guide, a cylindrical working pipe, and a slurry separation chamber. The objects of research were the dusty gas inlet and the main working pipe, with a diameter of 120 mm. The inlet gas velocity υ gas =5–25 m/s, the truncated cone working diameter d k =80, 90, 100 mm, and the water consumption Q s =0.07–0.378 m³/h were selected. The ranges were justified using gas consumption, cross-section ratio, conditional velocity in the cone zone, liquid-gas ratio, relative hydraulic resistance index, and an integrated visual assessment criterion developed in MATLAB. According to the results of computational-visual analysis, the range of d k = 90 mm, υ gas = 10–20 m/s, and Q s = 0.147–0.301 m³/h was selected as the initial rational experimental zone. However, the full study showed that it would be appropriate to maintain all specified ranges for assessing the boundary conditions, while d k = 90 mm, υ gas = 10–20 m/s, and Q s = 0.147–0.301 m³/h should be taken as the main concluding choice for the experimental range.	Wet dust collector, water curtain, truncated cone, gas velocity, water consumption, MATLAB, visual assessment criterion, L/G ratio, hydraulic resistance.

INTRODUCTION

In the process of cleaning fine dispersed dusts generated in industrial enterprises, dry inertial separators are not always sufficiently effective. Especially when dusts of a few micrometres in diameter, such as sulfur, mineral raw materials or cement, move with the gas flow, the inertia of the particles decreases, and it becomes difficult to retain them only under the influence of gravity or a simple cyclone. Therefore, wet dust collectors based on the collision of the gas flow with liquid droplets and a water film are of scientific and practical importance.

In the presented device, the dusty gas is introduced through a cylindrical pipe, water is sprayed through a nozzle, the gas-liquid flow is directed using a truncated cone, and the wetted particles are collected at the bottom in the subsequent slurry separation chamber. The cleaning efficiency in such a device depends not only on one parameter, but also on the interrelationship between gas velocity, water consumption, cone diameter, droplet screen density, flow acceleration, and hydraulic resistance.
The most important task at the initial stage of the study is to correctly determine the range of parameters to be changed in the experiment. If the range is narrow, the real capabilities of the device will not be revealed; if the range is chosen too wide, the number of experiments will increase, and some modes may be technically inefficient. Therefore, in this work, a research mode was chosen using physically based calculations, dimensionless ratios, and visual assessment criteria in the MATLAB software environment.

Research object

The principle of operation of the device is explained as follows: dusty gas is fed into the main working pipe, water is sprayed through the nozzle, and the droplets moving with the gas flow and the water film on the pipe wall trap dust particles. The truncated cone focuses the flow and enhances the collision of the gas with water droplets. The moistened dust falls down in the next chamber in the form of slurry, and the purified gas exits through the upper part.

Figure 1. General view of the device and main flow directions.

Figure 2. Water curtain, droplet screen, and dust particle capture mechanism.

In this article, the diameter of the dust inlet and main working pipe is assumed to be D=120 mm. When the working diameter of the truncated cone is taken as dk=80; 90; 100 mm, it gives relative diameters of 0.667; 0.750; 0.833 relative to the main pipe, respectively. These values cover the regimes of strong compression, medium compression and relatively mild compression of the flow.

Table 1. The main variable parameters adopted in the study

Parameter	Marking	Range	Step/levels	Justification content
Inlet gas velocity	*υ gas*	5–25 m/s	5; 10; 15; 20; 25	covers low, medium and high aerodynamic modes
Truncated cone diameter	*d k*	80; 90; 100 mm	3 levels	gives different compression coefficients for pipe D=120 mm
Water consumption	*Q s*	0.07–0.378 m³/h	0.070; 0.147; 0.224; 0.301; 0.378	evaluates water film formation, drop screen and sludge formation
Main pipe diameter	*D*	120mm	permanent	the main geometric parameter for gas consumption and L/G ratio calculations

Research methodology for calculating ranges

When determining the ranges, the goal was not to find a direct empirical optimum, but to separate a safe, physically meaningful and informative working area for further experimentation. Therefore, the methodology was carried out in three stages: first, the geometric and consumption parameters of the device were calculated; second, the modes were evaluated using derivative criteria; third, visual maps were constructed in the MATLAB environment and rational experimental zones were separated, and calculation formulas were introduced.

According to him:

The main working pipe cross-section is calculated according to the following formula, m 2 ;

Gas consumption is linearly dependent on the incoming gas velocity, m^3/h;

The relative cross-sectional area coefficient of a truncated cone and its conditional acceleration are expressed as follows;

The wet contact degree between water consumption and gas consumption was estimated through the *L/G ratio,* l/m^3*;*

where $Q\ s$ — water consumption in m^3/h, $Q\ g$ — gas consumption in m^3/h. It was assumed that the water droplet screen and the water curtain on the wall are stably formed when *the L/G* ratio is in the range of 0.3–1.2 l/m^3. Values less than 0.1 l/m^3 are considered as a limit regime indicating the risk of dry zone formation, and values greater than 1.8 l/m^3 are considered as a limit regime indicating the entrainment of liquid droplets and an increase in slurry consumption.

Table 2. Gas consumption and *L/G* limits for a pipe with *a diameter* of 120 mm

υgaz, m/s	*Qg*, m^3/soat	*L/G*, *Qs*=0,070 da, l/m^3	*L/G*, *Qs*=0,378 da, l/m^3
5	203.6	0.344	1.857
10	407.2	0.172	0.928
15	610.7	0.115	0.619
20	814.3	0.086	0.464
25	1017.9	0.069	0.371

Table 3. The cross-sectional area coefficient and the conditional velocity in the cone zone are determined by the values of *d k*

d k , mm	*d k /D*	*m =(d k /D)²*	*1/m*	*he/she /itrange, m/s*
80	*0.667*	*0.444*	*2.25*	*11.2–56.2*
90	*0.75*	*0.562*	*1.78*	*8.9–44.4*
100	*0.833*	*0.694*	*1.44*	*7.2–36.0*

Visual evaluation criterion in the MATLAB environment.

In the MATLAB software environment, the parameters were estimated based on a full-factor calculation plan. Here, a continuous array in the range of 5–25 m/s for *υ gas ,* a continuous array in the range of 0.07–0.378 m^3/h for *Q s , and levels of 80, 90, 100 mm for d k* were assumed. At each point, uk, *L/G* , relative resistance index, and diametrical compliance were estimated. The visual evaluation criterion *K viz* was taken as a normalised integral indicator from 0 to 1;

where *μ u* is the velocity function that ensures the collision of particles and water droplets in the cone zone; *μ L/G—* function assessing the adequacy of the water curtain and droplet screen; *μ ΔP* — function to reduce the risk of hydraulic resistance; *μ d* — function of the structural compatibility of the cone diameter with respect to a 120 mm pipe.

The L/G ratio was chosen to be high in the criterion because the main dust capture mechanism of the device is based on collisions with water droplets and water films. The velocity ratio was also taken to be high because if the gas flow does not have enough energy, small particles can pass through without colliding with the droplets.

The K values were interpreted as follows:

0–0.40 — ineffective or dangerous mode;

0.40–0.60 — borderline mode;

0.60–0.75 is an acceptable mode for the experiment.

0.75–1.00 — rational and priority research mode.

This criterion does not replace the final purification efficiency; it only serves as a computational-visual screening to select the experimental range and narrow down the experimental points.

Figure 3. Gas consumption range by inlet gas velocity.

Figure 4. Effect of $d\ k$ **values on the conditional velocity in the cone zone.**

Figure 5. *L/G* **ratio as a function of water consumption and gas velocity.**

Figure 6. Dangerous modes according to the relative hydraulic resistance index.

Figure 7. MATLAB visual assessment map for $d\ k$ **=80 mm.**

Figure 8. MATLAB visual assessment map for $d\ k$ **=90 mm.**

Figure 9. MATLAB visual assessment map for $d\ k$ **=100 mm.**

Results and Discussion

Calculations show that in a working pipe with a diameter of D = 120 mm , the gas flow rate at $\upsilon\ g$ = *5 m/s is 203.6 m³/h, and at* $\upsilon\ g$ = 25 m/s it is 1017.9 m³/h. Thus, the selected speed range allows the device to be evaluated from a low-flow laboratory mode to a high-load, near-industrial mode. The lower limit of 5 m/s is necessary to check the minimum collision between the water curtain and the gas flow; the upper limit of 25 m/s is necessary to assess high turbulence, droplet entrainment, and increased hydraulic resistance.

$d\ k$ =80 mm, the cross-sectional area coefficient is m =0.444, and the gas flow accelerates 2.25 times in the cone zone. In this mode, the probability of collision of particles with droplets is high, but at inlet gas velocities of 20–25 m/s, the conditional uk reaches 45–56 m/s, increasing the risk of hydraulic resistance and liquid entrainment. Therefore, $d\ k$ =80 mm was left in the experiment as a highly intensive, but energetically cautious option.

$d\ k$ =90 mm, m =0.563 and the acceleration coefficient is 1.78. In this case, in the range of $\upsilon\ g$ =10–20 m/s, uk is approximately 17.8–35.6 m/s. These speeds ensure active collisions of water droplets with particles, but the risk of resistance is lower than for $d\ k$ =80 mm. It was also seen in the MATLAB visual assessment maps that the area with *K viz >0.75 for* $d\ k$ =90 mm is larger. Therefore, this value is recommended as the main central option.

$d\ k$ =100 mm , m =0.694, and the flow acceleration is about 1.44 times. In this case, the hydraulic resistance is relatively low, but at low speeds, the droplet screen and particle collisions may not be strong enough . Therefore, $d\ k$ =100 mm is an important level for comparing energy-efficient, low-resistance modes of the device.

The choice of water flow rate *Q s =0.07–0.378 m³/h* allows changing the *L/G ratio within the general design range of 0.069–1.856 l/m³. This range is sufficient to compare the water shortage, stable water* *film and excess liquid regimes in the device in one experimental design. In particular, at high gas velocities, Qs* =0.07 m³/h may not be sufficient for dust capture; at low velocities, *Qs* =0.378 m³/h may increase the amount of excess moisture and sludge. Therefore, the central rational range for water flow rate was selected as *Qs =0.147–0.301 m³/h.*

K viz >0.75 on the visual assessment maps were accepted as priority experimental regimes. The general analysis showed that a rational operating regime was formed in the range of *d k* =90 mm, *υ g* =10–20 m/s and *Q s* =0.147–0.301 m³/h. However, for scientific purposes, it is important to maintain the full range: the lower limits serve to determine the minimum effective conditions of the device, and the upper limits serve to determine the hydraulic resistance and the risk of droplet entrainment.

For the first stage of the study, a fully factored matrix of the form 3×5×5 was recommended. In this case, 3 degrees for dk, *υ g. Assuming* 5 degrees for and 5 degrees for Qs, the total number of computational or experimental points is 75. This plan completely covers the main working area of the device and provides sufficient information for the subsequent regression model.

In the second stage, experiments are carried out in the zone with *K viz* >0.75. For example, for *d k =90 mm, additional testing can be carried out at the points υ g* =10, 12.5, 15, 17.5, 20 m/s and *Q s* =0.147, 0.224, 0.301 m³/h. At this stage, the main performance indicators are the cleaning efficiency η, the dust concentration at the outlet Cchiq, the total hydraulic resistance *ΔP um* , the slurry consumption *G sh* and the water droplet removal.

This approach allows us to isolate physically significant regimes rather than mechanically reducing the number of experiments. That is, the MATLAB visual assessment criterion acts as an initial filter for experiment planning, and the final optimal regime is determined based on experimental results and statistical processing.

Table 4. Recommended basic and additional modes for experimentation

Stage	*d k* , mm	*υ g* , m/s	*Q s* , m³/hour
Stage 1: Full range	80; 90; 100	5; 10; 15; 20; 25	0.070; 0.147; 0.224; 0.301; 0.378
Stage 2: Rational zone	90	10; 12.5; 15; 17.5; 20	0.147; 0.224; 0.301
Control modes	80 and 100	10; 15; 20	0.147; 0.224; 0.301

Conclusion

D = 120 mm, changing the inlet gas velocity υgas = 5–25 m/s allows controlling the gas consumption in the device in the range of 203.6–1017.9 m³/h. This makes it possible to cover the low, medium and high load operating modes of the apparatus in one system, to evaluate the interaction of the gas flow with water droplets and a water curtain under different aerodynamic conditions. At the same time, the selection of the truncated cone diameter with values of *d k* = 80, 90, 100 mm creates a cross-section coefficient in the range of 0.444–0.694 relative to the main pipe cross-section. As a result, it becomes possible to compare the flow regimes of strong compression, balanced compression and compression with low hydraulic resistance.

Changing the water flow rate in the range of *Q s = 0.07–0.378 m³/h* allowed us to estimate the *L/G ratio in the range of 0.069–1.856 l/m³. These indicators are important for determining the modes* *associated with the lack of a water film in the device, the formation of a stable wet contact, and excessive fluid consumption. On this basis, a visual assessment criterion, K viz,*was developed in the MATLAB environment to assess the relationship between water flow rate, gas velocity, and cone diameter. This criterion summarised the structural compatibility of gas velocity, *L/G* ratio, hydraulic resistance risk, and cone diameter on a scale of 0–1, and served as a computational and visual basis for selecting experimental ranges.

According to the results of computational and visual analysis, the range of δ_k = 90 mm, υ_g = 10–20 m/s and Q_s = 0.147–0.301 m³/h was selected as the initial rational research zone for the device. In these modes, sufficient acceleration of the gas flow in the cone zone, stable formation of a water curtain and droplet screen, as well as the absence of a sharp increase in hydraulic resistance, are ensured. However, when conducting a full experimental study, it is advisable to also maintain the boundary modes, since they serve to identify the states of the device that provide minimal efficiency, create excessive resistance and in which water droplet entrainment can be observed.

Therefore, the proposed computational-visual methodology is not considered a final optimisation method, but rather a preliminary screening tool for planning experiments, preliminary isolation of inefficient points and determination of a rational research area. The final optimal operating mode of the device should be determined based on such basic experimental indicators as cleaning efficiency η, total hydraulic resistance ΔP_{um}, dust concentration at the outlet C_{out} and generated sludge consumption G_{sh}.

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