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THEORETICAL RESEARCH OF A HEAVY POLLUTANT CLEANING DEVICE

OBIDOV AVAZBEK
Professor, Namangan Institute of Engineering and Technology
Phone.: (0593) 941-7775, E-mail.: aobidov@list.ru
**Corresponding author*

MIRZAAKHMEDOVA DILNOZA
Researcher, Namangan Institute of Engineering and Technology
Phone.: (0594) 302-2199, E-mail.: dmiraaxmedova@gmail.com

IBROHIMOV ILGORBEK
Researcher, Namangan Institute of Engineering and Technology
Phone.: (0593) 401-1311, E-mail.: iibrohimov@gmail.com

Abstract: In this article, an improved design of the device for trapping heavy impurities in raw cotton material is recommended. Theoretical studies have been conducted on this design and the results have been obtained. As a result of observing the operation of the crusher, it was established that even at an acceptable angle of deviation of the deflectors and deflectors, a sufficient amount of cotton raw materials will fall into the bunker intended for the impurities based on the turbulence of the air.

Keywords: Cotton raw materials, stone, heavy mixture, stone catcher, pipe, elastic coating, air velocity, pressure, efficiency.

Introduction. Currently, linear stone separators are widely used in enterprises. Because, in addition to their high efficiency in trapping heavy objects, they are also structurally quite simple [1-2].

A study of various linear stone separator designs has shown that all existing devices of this type have a low efficiency in trapping stones and that a large amount of cotton raw material is trapped in their bunkers designed for heavy mixtures.

In order to create optimal designs of linear stone separators that fully meet the requirements of the cotton industry, the author has created a model of the design that allows increasing the efficiency of various separation principles from cotton raw material (Fig. 1).

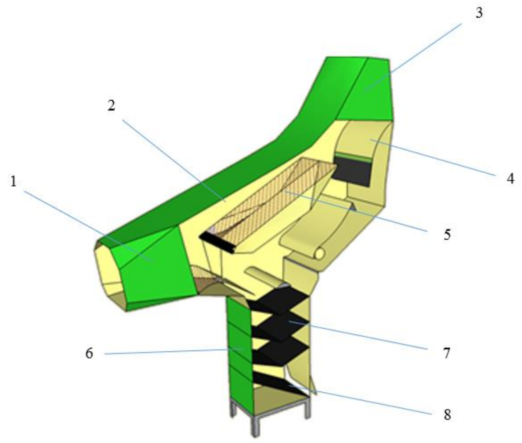

Fig. 1. Model of a heavy impurities separator

1-inlet pipe, 2-working chamber, 3-cotton outlet pipe, 4-elastic (rubber) coating, 5-cotton-squeezing barrier, 6-pocket for heavy impurities, 7-automatic heavy impurities discharge gates, 8-stone discharge plate

In this device, not only the effectiveness of various principles of separating heavy impurities was studied, but also methods for eliminating the main drawback of stone separators - the presence of cotton in the chamber - a pocket designed to collect stones were studied. The general view of the device shown in Figure 1 has an upper chamber 2, designed to study the speed of movement of mixtures of different weights. Here, the air speed is controlled by a movable barrier 5. Elastic coatings serve to determine the efficiency of separation as a result of the impact of stones on it, while the barrier 5, which periodically discharges heavy impurities and supplies air from the atmosphere to adjust the impact force, ensures that the cotton is thoroughly shaken in the separation chamber and does not get stuck with heavy impurities.

Theoretical research. Large and heavy mixtures move in pneumatic pipelines. Taking the observed movement of a large body along the wall as a forward motion [3-5], we write the kinetic energy change theorem, in which its final velocity must be equal to 0 (Fig. 2.7):

$$\frac{Gv_k^2}{2g} = \left(fGcos\alpha + Gsin\alpha - Fk\frac{v_{o'ır}^2\gamma}{2g}\right)l \qquad (1)$$

In formula (1), we substitute the following:

$$cos\alpha = \frac{1-tg^2\frac{\alpha}{2}}{1+tg^2\frac{\alpha}{2}} \text{ va } sin\alpha = \frac{2tg\ \frac{\alpha}{2}}{1+tg^2\frac{\alpha}{2}}$$

and $$\frac{Gv_k^2}{2g} = \left[\left(fG\frac{1-tg^2\frac{\alpha}{2}}{1+tg^2\frac{\alpha}{2}} + G\frac{2tg\ \frac{\alpha}{2}}{1+tg^2\frac{\alpha}{2}}\right) - Fk\frac{v_{o'ır}^2\gamma}{2g}\right]l \qquad (2)$$

The speed of the object (weight 1 kg, dimensions 80x80x100 mm) is approximately 2.3 m/s, the average speed of the air flow is 6.1 m/s, and the length of the guide wall is l = 0.6 m.

Based on these data, solving equation (2), we obtain the angle of deflection of the guide wall α = 8º, which agrees with the experimental data.

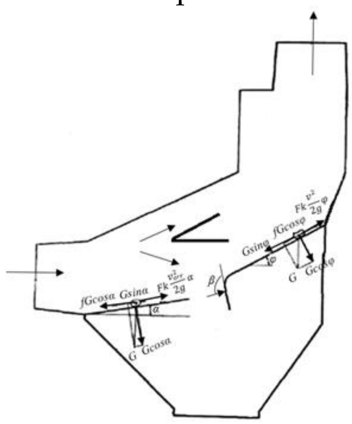

Figure 2. Scheme for determining the force and direction of impact of the body in different positions of the working bodies

Heavy impurities, having reached the bottom edge, have a somewhat higher kinetic energy and hit the opposite wall of the housing. In order to increase the efficiency of separation of heavy impurities, the return chute should have such a shape that the trajectory of the stones after impact should be directed downwards or along the inclined bottom. As a result, the rear wall of the bunker should be located at an angle of β = 90º to the inclined bottom [6-7].

Small and medium-sized stones moving together with cotton are poorly separated here, as a result of which the linear stone separator should be equipped with a special device for this device.

Operation of linear stone separators of various designs In practice, small impurities are separated more effectively in this case when the speed of the carrier air flow drops below their rotational speed to a value smaller than the speed of their rotation. For this purpose, the shape and dimensions of the stone crusher were chosen so that the air speed gradually decreases to 11-12 m/s, which is slightly lower than the rotation speed of the small stones. However, it is sufficient for continuous transportation of cotton, even cotton weighing 200 g.

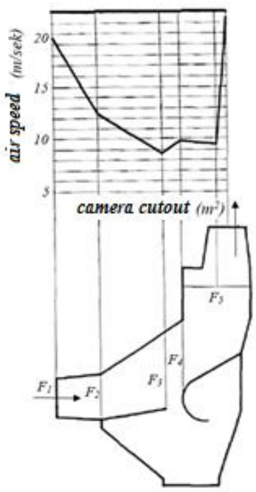

Figure 3. Variation of air velocity in different sections of the chamber

Based on the condition of constant air velocity at different points of the body (Figure 3), Table 1 was compiled. The data in this table correspond to a capacity of the crusher of 10-12 t/h.

Table 1. Air velocity versus chamber volume

Indicators	Plot number					
	1	2	3	4	5	6
Cross-sectional area of the stone catcher chamber (m²)	0,12	0,195	0,292	0,282	0,291	0,125
Air speed (m/sec)	20,0	14,0	8,8	10,14	9,5	21,0

(The air flow rate at the inlet to the ash collector is 2.5 m^3/sec, the amount of air sucked in through the outlet pipe is 0.2 m^3/sec).

To experimentally test the effect of the above chamber dimensions on the separation efficiency of heavy impurities, the stone separator was operated on grade III cotton at a load of 8-9 tons per hour in 2 positions of the wall.

The results of this study are presented in Table 2. The above-mentioned reduction of air velocity to an acceptable value due to the enlargement of the chamber showed an increase in the retention efficiency of the device to an average of 98%, which is higher than that of stone separators of the old design.

Table 2. Results of the study

Cotton variety	Capture efficiency, %				
	For stones 5 – 40 mm in size	For stones 40 – 60 mm in size	By metal objects	General	Average of 3 experiments
I	88,1	97,4	98,4	92,8	92,8
	90,8	97,3	98,8	94,6	
	91,1	98,0	99,2	94,2	
III	98,4	99,2	99,8	99,1	98,6
	96,0	98,1	99,6	98,4	
	97,5	99,1	99,5	98,5	

Since the cotton raw material falls on the return wall along with heavy impurities, the heavy impurities must move along the wall towards the pocket, and the cotton raw material, in turn, must continue to move along the flow direction, and when the flow stops, the cotton raw material will stop on the wall.

Based on the above, the angle of deviation of the wall should be greater than the angle of friction of the stones, and less than the friction of the cotton raw material.

The angle of friction should be 15º for stones (f = 0.29), 35º for cotton raw material (f = 0.67), then

$$15^{\circ} < \varphi < 35^{\circ}$$

$\varphi = 30^{\circ}$ we accept.

Therefore, installing the return wall at a greater or equal angle to the bunker, heavy and even fine impurities roll down in this place, as a result of which the stone crusher operates continuously.

In this case, part of the cotton raw material hits the back wall or the inclined part of the return wall and loses its initial speed, as a result of which it sinks down. Therefore, at a large angle of deviation of the return wall, the cotton raw material moves and falls into the bunker, as a result of which a blockage is observed in the stone crusher. To eliminate this drawback, it is necessary to eliminate the movement of cotton slivers into the bunker.

The cross-section of the first-grade cotton slivers that are not well spread is F=0.0015 m^2, the weight is $G_b=0.2$ *g*, $K=0.7$, and the coefficient of friction with steel is $f=0.67$.

In this case, to eliminate the fall of cotton into the stone crusher bunker, it is necessary to:

$$\varphi \leq 30^{\circ}$$

Thus, the acceptable deflection of the return wall, which ensures the effective operation of the stone crusher, should be within the following range:

$$\varphi = 26 \ldots 30^{\circ}$$

To determine the resistance coefficient (ξ) of the damper, we divide its chamber into 6 sections, the area of which is equal to the previously selected dimensions (Figure 3):

$$F_1 = 0{,}126\ m^2;\ F_2 = 0{,}197\ m^2;\ F_3 = 0{,}29\ m^2;$$
$$F_4 = 0{,}28\ m^2;\ F_5 = 0{,}29\ m^2;\ F_6 = 0{,}126\ m^2$$

As a result of the expansion of the chamber, the resistance coefficient at the entrance to it becomes the same as in a rectified flow diffuser [8], that is:

$$\xi_1 = \varphi\left(1 - \frac{F_1}{F_3}\right)^2 \qquad (3)$$

here $\varphi = 0{,}024\alpha - 0{,}1 sin7\alpha = 0{,}35$

($\alpha = 30^{\circ}$ - angle of expansion of the stone holder chamber)

For the assumed dimensions of the diffuser, $\xi_1 = 0.12$.

Atmospheric air is sucked in between the walls of the diffuser and the deflector, and it is equal to the actual speed and air consumption, and the local resistance coefficient is $\xi_2 = 0.11$.

When it reaches the vertical pipeline, the chamber expands and the direction of air movement changes.

The resistance coefficient at this point is equal to:

$$\xi_3 = \left(\frac{F_5}{F_4}\right)^2 + 0{,}2\left(\frac{F_4}{F_5}\right)^2 = \left(\frac{0{,}29}{0{,}28}\right)^2 + 0{,}2\left(\frac{0{,}29}{0{,}28}\right)^2 = 1{,}24$$

As the air exits the cooler, the chamber becomes smaller again. Here, the resistance coefficient is:

$$\xi_4 = 0{,}7\left(1 - \frac{F_6}{F_5}\right) - 0{,}2\left(1 - \frac{F_6}{F_5}\right)^3 = 0{,}7\left(1 - \frac{0{,}126}{0{,}29}\right) - 0{,}2\left(1 - \frac{0{,}126}{0{,}29}\right)^3 = 0{,}35$$

The total value of the resistance coefficient of the heater is:

$$\xi = \xi_1 + \xi_2 + \xi_3 + \xi_4 = 1{,}82$$

Based on aerodynamic measurements, the air consumption in the pipeline to the hopper at a rate of Q = 2.5 m^3/sec is equal to the loading of the hopper with 10–12 tons of cotton raw material.

The static pressure in the pipeline at a distance of 2 meters from the hopper to the hopper is 220 mm.w.s., the dynamic pressure is 58.4 mm.w.s., and the pressure is 732 mm.w.s., at a humidity of 1.15 kg/m^3 of 10–12%. Thus, the total pressure in the pipeline to the hopper is equal to:

$$H_n = H_{abv} - H_{d1} = 161{,}1\ mm\ above\ water.$$

In the pipeline 2 meters after the sprinkler, the static pressure is 302 mm.w.s., and the dynamic pressure is 38.9 mm.w.s., i.e. the total pressure is:

$$H_{n_2} = H_{abv_2} - H_{d2} = 213{,}1\ mm\ above\ water.$$

Also, the pressure loss in the rocker at the indicated loads is equal to:

$$H_n = H_{n_2} - H_{n_2} = 51{,}5\ mm\ above\ water. \qquad (4)$$

Result. The increase in dynamic pressure after the thresher occurred as a result of atmospheric air being sucked in through a slot in the pocket cover (0.2 m^3/sec). Due to the insufficient hermeticity of the thresher prototype body (0.21 m^3/sec), the working bodies were adjusted to prevent cotton from clogging in the bunker.

Thus, the data from aerodynamic measurements confirmed the previously calculated coefficient of local resistance of the thresher.

Theoretical analysis of the operation of the linear thresher made it possible to determine the optimal dimensions of its main working bodies and the design of the device.

As a result of observing the thresher operation, even at the optimal angle of deviation of the deflectors and deflectors, a sufficient amount of cotton raw material falls into the bunker intended for mixtures due to air turbulence, resulting in clogging.

To eliminate this drawback, the distance between the guide wall, the pocket cover and the return walls was increased to 130-150 mm. However, it was not possible to completely eliminate the falling of cotton balls into the pocket.

Therefore, a slot was installed in the pocket cover to suck in atmospheric air, with the help of which all the cotton raw materials that fell into the bunker were sprayed out.

In future tests of the thresher, it was aimed to determine the effect of loading the working bodies in optimal conditions on the separation of heavy impurities and the exit of cotton with these impurities.

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