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Theoretical study of stone catcher with many pockets during the primary cotton cleaning process

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ABSTRACT: In this paper we consider theoretically study of many pocket stone catcher. The quality of cotton fiber depends on primary qualitative processing of raw cotton. One of the operations of cotton processing consists of cleaning cotton from various impurities such as small and large things like a heavy stone. Such extraneous things must be removed before ginning process. To separate the heavy things of cotton, stone catchers are needed, that is installed between separator and cotton gin. Constructions of stone catchers are in different form such as cylindrical, rectangular in pipe bends. Cotton from bale transported by air at high speed through pipelines with a diameter of 0.2 - 0.3 Air speed is 15-20 m / s. In the rotary section of the pipeline installed stone catchers. Due to centrifugal forces of inertia, heavy impurities separated from the cotton move to the working chamber and stone catcher. There is need to examine the trajectory of cotton and heavy impurities in order to install the pocket

Based on these considerations viewed the probability approach to the stone catcher: determined the effect of catching depending on the geometric dimension of stones, studied movement of cotton and heavy impurities at the entrance of the separation chamber.

Equations of motion such as character movement, trajectory of cotton and heavy impurities are obtained with the help of principle of d'Alembert. According to the theory of motion of heavy impurities and raw cotton, found the optimal location of the pockets at the bottom of impurity.

KEYWORDS: Cotton gin, Stone catcher, cotton fiber, differential equation, d'Alembert, separator, theory of probability.

1 INTRODUCTION

Uzbekistan is one of the leading countries in the world in the production and processing of cotton. Production and provision of high-quality fiber is the main objectives of the Republic of Uzbekistan, therefore scientists lead many large-scale scientific researches.

Fiber quality depends highly on the primary processing of cotton. Since the processing of the cotton consists of the following techniques.

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- Aerodynamic transportation of cotton.
- Selection of the composition of light and heavy impurities from the cotton.
- Separation of air from the cotton
- Drying cotton
- Cotton ginning

Any disturbance in the cotton processing technology could impair the quality of the fiber, in addition during the process of cotton harvesting and transporting accidentally added about 0.2% -0.3% impurities to the harvest in the cotton factories. External impurities are in the form of various small stones that violate ginning process.

Therefore, it is necessary to allocate such harmful external small and large stones from the cotton before the ginning process.

The authors of this article have developed various stone catchers, which are installed in the chain of cotton processing technology. Such construction requires the right approach to the theoretical studies on the movement of cotton and external small heavy impurities in the chamber of stone catcher. Based on theoretical studies determined the optimal parameters of geometrical sizes of stone catcher.

2 MATERIALS AND METHODS

2.1 A PROBABILISTIC APPROACH TO THE STUDY OF STONE CATCHER.

Existing catchers of heavy impurities have a limited ability to release the heavy impurities from the transported material, it depends on a variety of indicators of cotton such as design, geometric shape and operation of the device designed for this purpose. At the same time, operation of stone catcher is significantly affected by the size of the pocket. The useful section defines the possibility of loss of heavy impurities that are transported flow due to a significant proportion of heavy impurities in respect of cotton.

When the size of the pocket expands, "useful section" of catcher will increase, and useful section decreases by making the size of catcher smaller. However, experience shows that increasing the useful section by expanding the size of the pocket is the main reason for the failure of catcher. Raw cotton that is hit in the pocket leads to rapid filling then inactivates the pocket and cotton with heavy impurities. Therefore, a significant expanding the pocket is not advisable.

Increasing "good ratio" can be achieved by increasing number of pockets in the separation chamber of stone catcher, while ensuring maximum loosening cotton, which also contributes to increase catching effect of device. It is known that while existing stone catcher is working, catching effect is on average 60%. The analysis shows that when various stones are skipped through an existing stone catcher its catching effect changes as follows (see Table I)

Stone size in mm	10-15	15 - 20	20 – 30	30 - 50
Trapping effect of CHTL in percentage	45	56	82	95

To study the influence of the number of pockets on the catching effect and determine the optimal number of pockets using a probabilistic approach, believing that the pockets work independently.

Since large heavy impurities mixed up mainly on the bottom of the pipe, it can be assumed that the highest probability of their loss in the first pocket. Mainly medium-sized impurities fall in the second pocket and large impurities not captured in the first pocket. [3]

Stone catcher’s trapping effect can be determined from the following formula when two pockets installed.

$$P^{(p)} = P(A_1 or A_2) = P(A_1) + P(A_2) - P(A_1 \cdot A_2) \qquad (2.1)$$

Where A and A1 - independent random events, ie first and second pockets operate independently

According to formula (2.1) determine the probability of catching stones when two pockets installed (see Table 2).

Stone size in mm	10-15	15-20	20-30	30-50
Chance of catching stones in stone catcher with two pockets, in %	66,44	80,84	97,2	99,7

Analyzing the impact of installing second pocket, determined the probability of collecting stones from raw cotton increased in the following order: on the rocks with up to 50 mm - 4.7%;

30 mm - 15.2%; 20 mm - 24.84%; 15 mm - 21.44%

Similarly, we define the probability of selection of stones after installing third pocket at the independent work of all three pockets.

Chance of catching in three pockets defined by the formula:

$$P^{(p)} = P(A_1 or A_2 or A_3) = P(A_1) + P(A_2) + \\ + PA_3 - P(A_1A_2) - P(A_1A_2) - P(A_2A_3) + P(A_1A_2A_3) \tag{2.2}$$

where: A3 - independent random event.

Probability of capturing stones from raw cotton after installing third pocket in accordance with formula (2.2) is equal to (see Table 3).

Table 3

Stone size in mm	10-15	15-20	20-30	30-50
Chance of catching stones in stone catcher with three pockets, in percentage	86,8	94,6	98,1	99,9

The stones can be found in the transporting raw cotton with size of 50 mm - 0.02%; 30 mm - I, I%; 20 mm - I3, 76%; 15 mm - 20%.

The research about the probability of catching stones by installing fourth pocket showed that while catching effect of stone catcher hardly increases, both large and small impurities that militate against a further increase in the pockets.[4],[5]

Theoretical studies on selecting the number of pockets in the stone catcher show the optimal providing.

High catching effect of working chamber with three pockets was confirmed by probabilistic approach.

2.2 MOTION STUDY OF COTTON AND HEAVY IMPURITIES ACCORDING TO THEIR DIVISION IN THE CHAMBER OF STONE CATCHER

In the previous chapter, on the basis of the probabilistic approach, selecting the optimal number of pockets stone catcher, proved that the best is to put three pockets in the separation chamber, further increase in the number of pockets gives sizeable increase in catching effect, but creates difficulties in production and operation, and also causes unjustified increase in hydraulic resistance.[6],[7]

Results of previous studies, as well as visual analysis of the movement of raw cotton in the pipeline show the uneven distribution of cotton in its transportation along the section of the pipeline, as well as the characteristic movement of heavy impurities.[4],[8],[9]

Depending on the mode of transport, mainly on the concentration of the mixture, or the performance and speed of transport, raw cotton and heavy impurities get mixed at different levels of pipeline section: to increase cotton trajectory of cotton, mixed-down occurs in the lower parts of the pipeline. This clearly explains that heavy impurities get mixed in the bottom of the main conduit.

Under the initial condition, according to figure 2.2 M is accepted a material point moving through air suction force λv and gravity $P = m \cdot q$, where: ($m -$ weight kg - acceleration of gravity). To study the motion of a point M hold-axes OX and OY from the center of curvature and form the equation of equilibrium of a material point on the principle of d'Alembert, directing the force of inertia against the direction of the driving force $J = -m \cdot w = m\ddot{s}$, we find the projection of forces λv to the axes OX and OY.

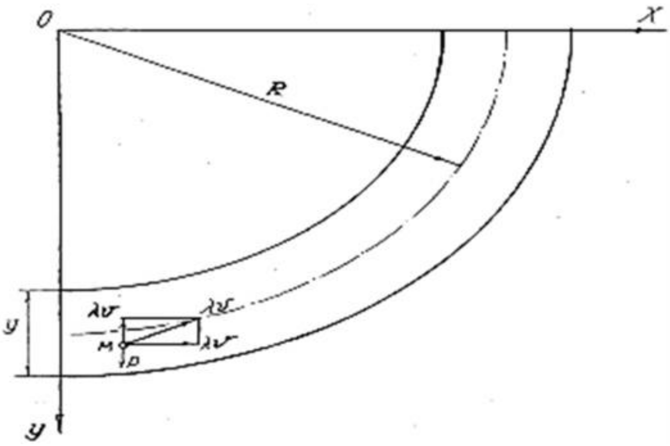

Fig. 2.2. Movement of raw cotton and heavy impurities

We find the projection of forces to the axes OX and OY

$$\left.\begin{array}{l}\Sigma X_i = 0 \\ \Sigma Y_i = 0\end{array}\right\} \rightarrow \begin{cases} m\ddot{x} = -\lambda \cdot v_x + P_x \\ m\ddot{y} = -\lambda \cdot v_y + P_y \end{cases} \tag{2.3}$$

where: w - acceleration of raw cotton, m/s^2

$\ddot{x}$ - the second time derivative of the distance - a component of the acceleration of w on the OX-axis and $-\ddot{y}$ axis OY.

According to Fig.2.2: $Px = 0$, $Py = P = m \cdot q$ it is also known that $v_x = \dot{x}; v_y = \dot{y}$ i.e. speed - the time derivative of the distance.

The system (2.3) takes the following form:

$$\begin{cases} m \cdot \ddot{x} = \lambda \cdot \dot{x} \\ m \cdot \ddot{y} = mq - \lambda \dot{y} \end{cases} \tag{2.4}$$

For the initial conditions when

$$\begin{cases} x(0) = 0 \\ \dot{x}(0) = v_0 \end{cases} \tag{2.5}$$

$$\begin{cases} y(0) = h \\ \dot{y}(0) = 0 \end{cases} \tag{2.6}$$

where: h - the height (diameter) of the pipeline.

We find the general solution of the system of homogeneous equations:

$$\begin{cases} \ddot{x} = \dfrac{-\lambda}{m} \cdot \dot{x} \\ \ddot{y} = -\dfrac{\lambda}{m} \cdot \dot{y} \end{cases} \tag{2.7}$$

If we represent $x(t) = e^{kt}$ and $y(t) = e^{et}$ the system of characteristic functions is represented as follows:

$$\begin{cases} k^2 - \dfrac{\lambda}{m}k = 0 \\ e^2 \mp \dfrac{\lambda}{m}e = 0 \end{cases} \tag{2.8}$$

from which we have: $k_1 = 0$; $k_2 = \dfrac{\lambda}{m}$; $e_1 = 0$; $e_2 = +\dfrac{\lambda}{m}$ general solution of the equation has the form:

$$\begin{cases} x(t) = c_1 + c_2 e^{-\frac{\lambda}{m}t} \\ y(t) = c_3 + c_4 e^{-\frac{\lambda}{m}t} \end{cases} \tag{2.9}$$

To find the general solution of (2.3), we find a particular solution of inhomogeneous equations of the variation method. Particular solution represented in the form:

$$y(t) = c_3(t) + c_4(t)e^{\frac{\lambda}{m}t} \tag{2.10}$$

To locate $c_3(t)$ and $c_4(t)$ construct the following systems:

$$c^1{}_3(t) + c^1{}_4(t)e^{-\frac{\lambda}{m}t} = 0$$

$$c^1{}_3(t)\cdot 0 + c^1{}_4(t) - \left(\frac{\lambda}{m}e^{-\frac{\lambda}{m}t}\right) = q \tag{2.11}$$

Taking into account (2.11)

$$c_4(t) = -\frac{qm^2}{\lambda^2}\cdot e^{\frac{\lambda}{m}t}$$

$$c_3(t) = -\frac{qm}{\lambda}t \tag{2.12}$$

Substituting $c_3(t)$ and $c_4(t)$ in 2.10 we obtain:

$$x(t) = c_1 + c_2 \cdot e^{\frac{\lambda}{m}t}$$

$$y(t) = c_3 + c_4 \cdot e^{-\frac{\lambda}{m}t} + \frac{qm}{\lambda^1}t + \frac{qm^2}{\lambda^2} \tag{2.13}$$

Thus the general solution of the system (2.3) has the form:

$$y(t) = \frac{qm}{\lambda}t + \frac{qm^2}{\lambda^2} \tag{2.14}$$

Define constants c_1, c_2, c_3, c_4, c_5 using the initial conditions (2.5) and (2.6) has the form:

$$x(t) = \frac{-v_0 m}{\lambda}(e^{-\frac{\lambda}{m}} - 1)$$

$$y(t) = h + \frac{mq}{\lambda}t + \frac{qm^2}{\lambda^2}(e^{\frac{\lambda}{m}t} - 1) \tag{2.15}$$

The system of equations (2.15) represents the law of material flow in bends of pipeline, and is equivalent to Equation of flying cotton and heavy impurities, i.e respectively substituting m- weight values, λv so the suction force can be obtained for the corresponding equation of flying and heavy impurities. Heavy impurities equation can be displayed on the weight fraction, after finding the law of motion of a material point define the trajectory equation of motion of this point, what we want to exclude from the equation t.

The first equation is motion of a point of law that solves on the time t, and substitutes its Second equation. Thus we find the formula to construct the trajectory of motion of a material point M. substituting the corresponding values for flying cotton and individually by weight fractions of heavy impurities; we can get the appropriate path of movement for raw cotton and heavy impurities by weight fractions.

It is known that the equation of a circle with center (0,0) and the radius r, has the form

$$x^2 + y^2 = r^2 \tag{2.16}$$

Intersection point of flying impurities trajectory in the pipeline, with a circle of radius R, defines the solution of the following system:

$$\begin{cases} y - h - \dfrac{qm^2 n}{\lambda n}\ell n(1 + \dfrac{\lambda n}{mn \cdot v_0^{(m)}}x) + \dfrac{\dfrac{q \cdot mn}{\lambda n \cdot v_0^{(n)}}x}{1 + \dfrac{\lambda n}{mn \cdot v_0^{(n)}}x} = 0 \\ x^2 + y^2 = r^2 \end{cases} \tag{2.18}$$

If $y = \pm\sqrt{r^2 - x^2}$, we obtain the equation for x:

$$\sqrt{r^2 - x^2} - h - \frac{qm^2}{\lambda}\ell n(1 + \frac{\lambda_1}{mv_0}x) + \frac{\dfrac{q \cdot m}{\lambda \cdot v_0}}{1 + \dfrac{\lambda}{mv_0}x} = 0 \tag{2.19}$$

Equation (2.19) can not be represented in terms of elementary functions, so considered the following approximate cases: First case: let

$$\ell n(1 + Z) = Z and \frac{1}{1 + Z} = 1 \tag{2.19}$$

Then we obtain

$$\begin{cases} x = \sqrt{r^2 - h^2} \\ y = h \end{cases} \tag{2.20}$$

(2.20) - is a solution of (2.18).

Second case: let

$$\ell n(1+Z) = Z - \frac{Z^2}{2};\ \frac{1}{1+Z} = 1 - Z$$

then substituting these. Approximate expressions in (2.19) we have:

$$\sqrt{r^2 - x^2} - h - \frac{q}{2{v_0}^2}x^2 = 0 \tag{2.21}$$

From (2.21) it follows that the law of motion of raw cotton in the line described by the equation

$$y = h + \frac{q}{2{v_0}^2}x^2 \tag{2.22}$$

Now we find the roots of (2.21):

$$y - h - \frac{q}{2{v_0}^2}(r^2 - y^2) = 0 \tag{2.23}$$

$$y - h - \frac{qr^2}{2{v_0}^2} + \frac{q}{2{v_0}^2}\cdot y^2 = 0$$

$$y^2 + \frac{2{v_0}^2}{q}y - (r^2 + \frac{2{v_0}^2 \cdot h}{q}) = 0$$

$$d = \frac{4{v_0}^4}{q^2} + 4(r^2 + \frac{2{v_0}^2 \cdot h}{q}) \geq 0$$

$$y_1 = -\frac{{v_0}^2}{q} + \sqrt{\frac{{v_0}^4}{q^2} + \frac{2{v_0}^2 h}{q} + r^2}$$

$$y_2 = -\frac{{v_0}^2}{q} + \sqrt{\frac{{v_0}^4}{q^2} + \frac{2{v_0}^2 h}{q} + r^2}$$

$$x = \pm\sqrt{r^2 - y^2}$$

$$x_1 = +\sqrt{r^2 - (\frac{{v_0}^2}{q} + \sqrt{\frac{{v_0}^4}{q^2} + \frac{2{v_0}^2 h}{q} + r^2})^2}$$

$$x_2 = -\sqrt{r^2 - (\frac{{v_0}^3}{q} + \sqrt{\frac{{v_0}^4}{q^2} + \frac{2{v_0}^2 h}{q} + r^2})^2}$$

Thus, the coordinates of the intersection point

$$y = h + \frac{q}{2{v_0}^2}\cdot x^2; x^2 + y^2 = r^2$$

Indicated in Fig. 2.3 loci crossing trajectories of heavy impurities with a circumference wall (point indicated with an asterisk) separation chamber has a location slots, i.e establishing pockets and a place of the magnetic device.

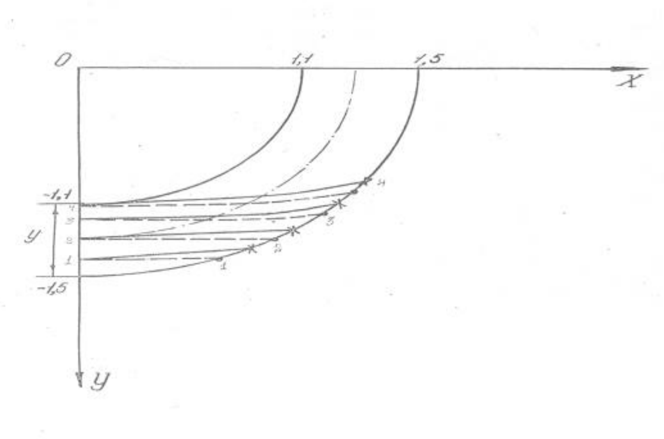

Figure 2.3

Thus, according to the motion theory of heavy impurities and cotton found the optimal location of pockets and magnetic device for the new catcher of heavy impurities from raw cotton.

3 RESULTS

The location of pockets for catching impurities was defined by probabilistic approach to the study of stone catcher. It is established the probability of catching stones from raw cotton, depending on the size of impurities. Theoretical studies have shown that the optimal effect of providing high capture is that working chamber with three pockets. This is confirmed by the calculations of probabilities. A system of equations received which is the law of motion of the material in the pipe bend. According to the theory of motion of heavy impurities and raw cotton, found the optimal location of the pockets on the pipe bend. On the basis of theoretical research, the author proposed new catching construction of heavy impurities from raw cotton.

4 CONCLUSION

1. The models of stone catcher and the analysis of work based on selected many pocket construction of magnetic stone catcher.
2. A scheme of the experimental construction, and the pneumatic installation conveyor for balanced distribution, with production parameters adapted to control performance and high-speed mode, prepared methodology for conducting experimental studies and aerodynamic measurements.
3. On the basis of the probabilistic approach to selecting the number of pockets on stone catcher shown that the optimal placements are three pockets.
4. The theoretical results are allowed to determine the trajectory of cotton and heavy impurities in the separation chamber. Defined by the point of intersection of heavy impurities from the bottom wall of the separation chamber, allowing the optimal location of pockets in which provides a more efficient capture of heavy impurities from raw cotton.

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