Theoretical analysis of the movement trajectory of a cotton piece thrown from the pile surface

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Abstract. The article contains information about the theoretical analysis of the trajectory of the cotton piece thrown from the surface of the piled drum in the 1XK aggregates available in cotton ginning enterprises. For this, in the recommended cleaning equipment, cotton pieces are dragged through the mesh surface by hanging the drum piles, and the separated impurities fall through the holes of the mesh surface. The piles eject the cotton piece at the appropriate speed. A piece of cotton moves in different trajectories depending on the value of the initial exit velocity and its mass. In this case, it is necessary to determine the impact zone of pile drums located in a row in the zone of cleaning cotton from small impurities. The results of theoretical studies on determining the mathematical model of the movement of cotton pieces along a drum with piles are presented. The problem of determining the impact zone of the next pile drum depending on the movement trajectory after the cotton piece is thrown from the surface of the pile drum in the process of cleaning cotton from small impurities has been solved. The value of the distance between the axis of pile drums was based on the analysis of the obtained trajectories of the movement of cotton particles and the constructed graphical relationships. In addition, the movement of cotton particles along the surface of the piles was analyzed. The results were obtained by analyzing the movement of a piece of cotton under the influence of external forces in order to ensure the transmission of small impurities separated from the mesh surface of the 1XK equipment, which is currently used in production, and the impact of the pile drum on the cotton flow.

1. Introduction

Today, as in all industries, several innovations are happening in the field of cotton ginning clusters. A number of activities are being carried out to obtain a competitive product that meets the requirements of the world market by introducing resource-saving technologies in cotton ginning enterprises. Decision No. PQ-308 defines the tasks of increasing cotton productivity, introducing additional organizational measures of science and innovation in cotton cultivation.

The use of cotton fibers in the world textile industry makes up 55-60 percent of the total amount of fibers. Consistent and stable development of the cotton ginning industry, introduction of modern equipment in branch enterprises, increasing the level of efficient and rational use of production capacity, production of competitive products in the world cotton market are considered the basis. In this regard, special attention is paid to the improvement of high-efficiency cotton ginning equipment and the creation of resource-efficient technologies in the global cotton ginning industry [1, 2].

In the world experience, scientific and research work is being carried out on a large scale to improve the technique and technology of the initial processing of cotton. In this field, among other things, tasks are set to develop effective technologies for cleaning cotton from impurities, to create resource-efficient and effective equipment for drying and cleaning cotton. Scientific research in the direction of identifying the factors that have a negative effect on the quality and quantity of the product at each stage of production and technical solutions to eliminate them, to develop technologies that can control the quality of the product, to maintain the initial quality indicators during the technological process of cleaning cotton, to optimize the performance modes and indicators. It is very important to carry out. For this purpose, it is necessary to carry out scientific research on identified deficiencies in 1XK aggregates and cleaning equipment installed in cotton ginning enterprises, and to improve the equipment [3-5].

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2. Methods

It is known that in the existing 1XK aggregates and in the proposed cleaning equipment, cotton pieces are dragged through the mesh surface by hanging the drum piles, and the separated impurities fall through the holes of the mesh surface. The piles eject the cotton at a certain speed. A piece of cotton moves along a trajectory depending on the value of the output speed, as well as its weight. In this case, it is necessary to determine the zone of influence of piled drums located in a row in the chamber for cleaning cotton from small impurities. In order to increase the efficiency of cleaning, theoretical research shows that it is necessary to pay special attention to the following:

- the law of movement of cotton with the surface of the pile;
- the speed and trajectory of the piece of cotton;
- setting the condition for the cotton piece to fall into the next pile drum;
- distances between the axes of pile drums [6-9].

We analyze the movement of cotton particles along the surface of the piles. The 1XK equipment, which is currently used in production, is equipped with the movement of the cotton piece under the influence of external forces in order to ensure the transfer of small impurities separated from the mesh surface and the impact of the pile drum on the cotton flow. The diagram of the impact forces is presented in Fig. 1.

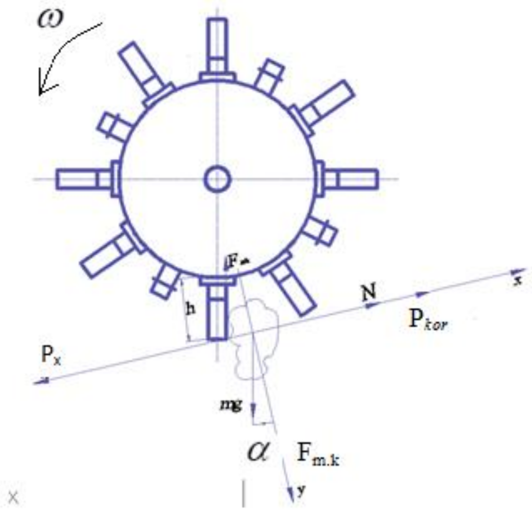


Fig. 1. Scheme of movement of a piece of cotton in a pile drum: mg – the weight of a piece of cotton; kv^2 – air resistance; $2m\omega^2\dot{x}$ - Cariolis force; $m\omega^2 h$ – centrifugal force; N – pressure force; h- the length of the arcuate pile

The following external forces are generated as a result of the movement of the cotton piece to the drum with the next pile under the influence of the piles.

$$F_{m.k} = m\omega^2 h; \quad P_x = kv^2; \quad P_{kor.} = 2m\omega^2\dot{x}; \quad F_{ish} = \mu \cdot N \qquad (1)$$

Here we take the length of the piles as h.

We develop the law of motion in the transfer of impurities between the mesh surface, taking into account the frequency of rotation of the pile drum and the external forces acting on the cotton piece. For this, we construct the differential equations of motion of the Dekart coordinate system [10, 11].

$$\begin{cases} -kv^2 + N - 2m\omega\dot{x} - mg\sin\alpha = m\ddot{y} \\ m\omega^2 h + mg\cos\alpha - \mu N = m\ddot{x} \end{cases} \qquad (2)$$

here, the normal pressure $N = mg\cos\alpha$ acting on the cotton piece is determined.

Putting it into equation (2), we get the following expression. Using this expression, we theoretically analyze the process of removing impurities from cotton, and taking into account the relationship, we can write the equation in the following form:

$$\begin{cases} kv^2 + q\cdot l - 2m\omega\dot{x} - mg\sin\alpha = m\ddot{y} \\ m\omega^2 h + mg\cos\alpha - \mu\cdot q\cdot AB = m\ddot{x} \end{cases} \qquad (3)$$

The angular velocity of the rotating drum changes according to the law as follows: $\alpha = \omega t$

$$\begin{cases}\frac{k}{m}v^2+\frac{ql}{m}-2\omega\dot{x}-g\sin\alpha=\ddot{y}\\ \omega^2h+g\cos\alpha-\frac{\mu q}{m}l=\ddot{x}\Rightarrow\end{cases}$$

$$\Rightarrow\dot{x}=\left(\omega^2h-\frac{\mu ql}{m}\right)t-g\omega\sin\omega t+c_1 \qquad (4)$$

From the initial condition $\dot{x}_{t=0}=0\Rightarrow c_1=0$ here

We take $\dot{x}=\left(\omega^2h-\frac{\mu ql}{m}\right)\cdot t-g\omega\sin\omega t$ into account and put it in equation (4).

$$\frac{k}{m}v^2+\frac{ql}{m}-2\cdot\omega^3ht+\frac{2\omega\mu ql}{m}t+2\omega^2g\omega\sin\omega t-g\sin\omega t=\ddot{y}$$

$$\dot{y}=\left(\frac{ql}{m}+\frac{k}{m}v^2\right)\cdot t-2\omega^2h\cdot\frac{t^2}{2}+\frac{2\omega\mu ql}{m}\cdot\frac{t^2}{2}+2\omega^3g\cos\omega t+c_2$$

From the initial condition $(\dot{y})_{t=0}=0\Rightarrow c_2=0$ here

$$y=\left(\frac{ql}{m}+\frac{k}{m}v^2\right)\cdot\frac{t^2}{2}+\left(\frac{2\omega\mu ql}{m}-2\omega^2(R_6+h)\right)\cdot\frac{t^3}{2}-2\omega^4g\sin\omega t+c_4$$

Based on the boundary condition $(y)_{t=\tau}=L\Rightarrow$ here τ –time

$$L=\left(\frac{ql}{m}+\frac{k}{m}v^2\right)\cdot\frac{\tau^2}{2}+\left(\frac{\omega\mu ql}{m}-\omega^2h\right)\cdot\frac{\tau^3}{3}-2\omega^4g\sin\omega\tau \qquad (5)$$

Equation (5) represents the equation of motion in the transfer of a piece of cotton in a piled drum.

When a piece of cotton is thrown from a pile, it is mainly affected by the weight of the cotton and the resistance of the air. It is presented in the calculation scheme (Fig. 2). In accounting books, the system of differential equations representing the law of motion of a piece of cotton in a drum with a pile is as follows [12,13]:

$$mn\frac{d^2y_1}{dt^2} = -mn\,g - Fx\sin\alpha_1$$

$$mn\frac{d^2x_1}{dt^2} = -\,Fx\sin\alpha_1 \qquad (6)$$

here: α_1- angle between the x-axis and the velocity vector of the piece of cotton thrown from the surface of the pile.

To get the second equation of the system of equations (6), we integrate it twice over time [14]:

$$\frac{dx_1}{dt}=c3 \quad \text{and} \quad x1 = c3\,t + c1 \qquad (7)$$

By initial condition t = 0, c3 = 0 , c4 = υncos α_1

In that case, the solution is as follows:

$$X1 = \upsilon nt\cos\alpha_1 \quad \text{and} \quad \frac{dx_1}{dt}=\upsilon n\cos\alpha_1 \qquad (8)$$

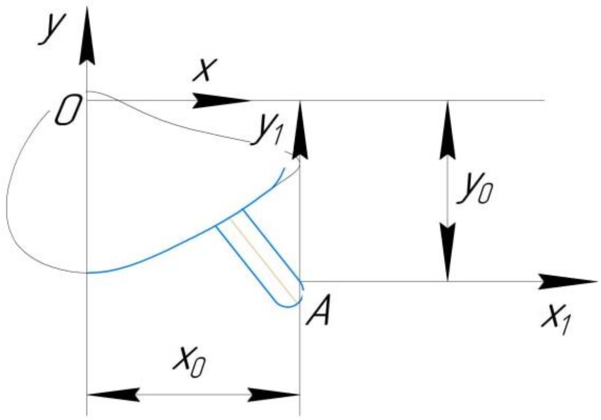


Fig. 2. The scheme of the coordinates of a piece of cotton when it is thrown from the surface of the pile

Based on the equation in Figure 2, it can be written as follows:

$$X = x0 + \upsilon nt\cos\alpha_1,$$

$$У = y0 + \frac{t^2}{2}(g+k\upsilon_x^2\ \sin\alpha_1)+\upsilon nt\cos\alpha_1 \qquad (9)$$

In this:

$$\upsilon n = \omega б\,[Rб + (h - \frac{1}{2}\,h_п)] \qquad (10)$$

here: h – pile length;

$h_п$ – length of piece of cotton.

Also

$$x0 = [Rб +(h-\frac{1}{2}\ h_п)]\sin \varphi_1;$$
$$y0 =[Rб +(h-\frac{1}{2}\ h_п)]\cos \varphi_1 \quad (11)$$

Numerical solutions of obtained equations (7) and (9) were carried out at the following values:

Rб =(0,130-0,165) m; ωб = (35,0-55,0) s^{-1}; Hб = (0,7-1,1) 10-1 m;
mn = (0,2-0,7) 10-3 kg, x0 = (0,11-0,15) m; y0 = (0,08-0,09) m;
Vn = (4,5-8,0) m/s.

3. Results and Discussion

The movement trajectories of the cotton pieces ejected from the surface of the piles of the drum piles in the cotton cleaning aggregates depend on a number of parameters, the mass of the cotton piece and the value of the initial linear velocity are the most important of them.

As a result of the calculation, the movement trajectory was obtained, the obtained results are shown in Figures 3, 4, 5 and 6. For example, according to the analysis of the trajectory of m in Figure 3, when the weight of the piece of cotton is 0,2 10^{-3} kg, that is, when it consists of one seed, and the angular speed of the piled drum is 38 s^{-1}, the piece of cotton rises up to 0,134 m in the direction of the y-axis, and is absorbed up to 0,3 m in the direction of the x-axis. Correspondingly, when a piece of cotton weighs 0,85 10^{-3} kg, that is, when it consists of at least four seeds, the trajectory of movement changes by only 0,073 m in the direction of the y-axis, while it changes by 0,221 m in the direction of the x-axis. In this case, the impact of the next pile drum is required to be obtained by the dashed line shown in Figure 3, that is, the distance between the axis of the pile drums along the x-axis:

$$X = x0 + 0,227\ м + Rap \quad (12)$$

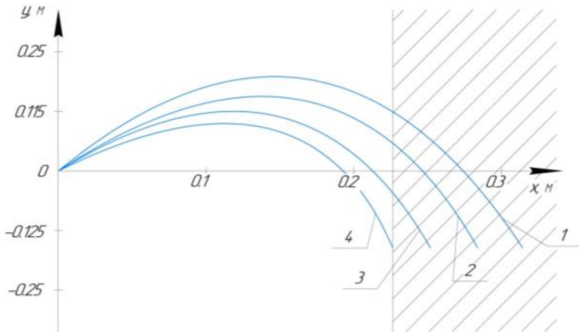


Fig. 3. When a piece of cotton is thrown from the surface of the pile, the law of change of the subsequent movement trajectory depending on the weight of the cotton

If the pile drum radius is 0,20 m, then x = (0,54-0,61) m.

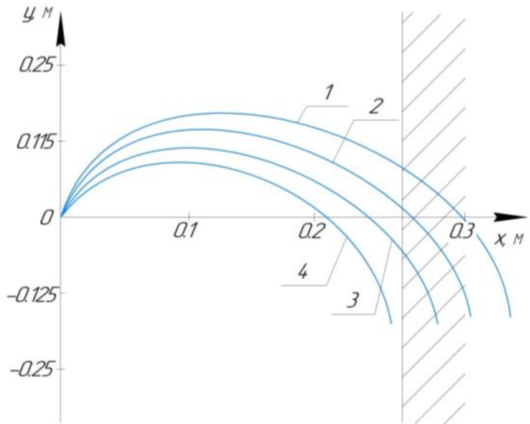


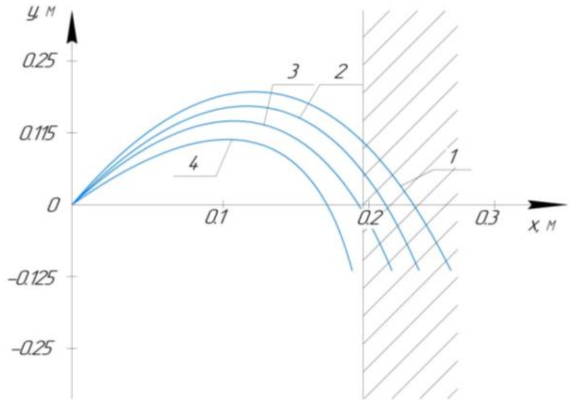
Fig. 4. Laws of changing the trajectory of the cotton piece after leaving the surface of the pile depending on its weight: 1 -mn =0,2*10^{-3} kg; 2 -mn =0,35*10^{-3} kg; 3 -mn =0,55*10^{-3} kg; 4 -mn =0,85*10^{-3} kg; ωб = 0,52 s^{-1}

Therefore, the cotton must be sufficiently stretched to increase their impact, if the distance between the pile drum axles does not change. It is also required to increase the angular speed of the pile drum to a certain value.

The coordinates of the change of the movement trajectory of the piece of cotton after leaving the surface of the pile depending on its weight are given (Fig. 4). In this case, solutions were obtained for the case where the angular velocity of the piled drum was increased to 0,525 s^{-1}. In Figure 4, the area of influence on the next pile drum is shown separately.

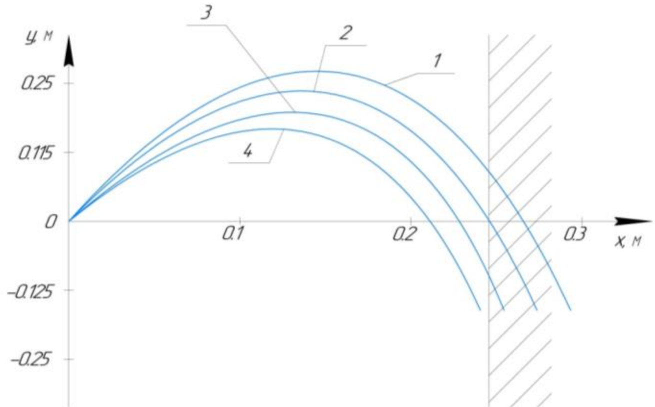
Based on the expression in (12), it is recommended to take piled drums in the range of (0,65-0,68) m between the piled drums on the x-axis when the angular speed increases to 0,52 s^{-1}.

Correspondingly, Figure 5 shows the laws of change of the movement trajectory of a piece of cotton after it is thrown from the surface of the pile, depending on its initial linear speed. Based on the analysis, when the weight of the piece of cotton is 0,4*10^{-3} kg and the initial linear velocity is 8,5 m/s, the piece of cotton is absorbed up to 0,231 m in the x-axis direction, and up to 0,132 m in the y-axis direction.



1- Vn = 8,5 m/s; 2- Vn = 6,8 m/s; 3- Vn = 5,3 m/s; 4- mn = 0,4*10^{-3} kg

Fig. 5. Changes in the trajectory of a piece of cotton when it is thrown from the surface of the pile depending on its initial linear speed



1- Vn = 8,5 m/s; 2- Vn = 6,8 m/s; 3- Vn = 5,3 m/s; 4- Vn = 4,5 m/s; mn = 0,2*10^{-3} kg

Fig. 6. When a piece of cotton is thrown from the surface of a pile, the trajectory changes depending on its initial linear velocity

When the linear velocity changes to 4,5 m/s, the trajectory of the piece of cotton is absorbed up to 0,187 m in the direction of the x-axis and up to 0,103 m in the direction of the u-axis. The impact zone on the next pile drum starts at 0,192 m and the axle spacing is 0,588 m.

4. Conclusions

Cotton picking is further improved and the mass of one seed with fiber becomes, that is, when mn=0,2*10^{-3} kg (Fig. 6), its trajectory is acceptable, and the impact zone of the piled drum along the x-axis reaches 0,252 m. In this case, it is advisable to take the distance between the axis of the drums in the range of (0,52-0,57) m.

According to the results of the theoretical studies conducted in order to improve the pile drums of 1XK machines for cleaning cotton from small impurities, it is appropriate to choose the impact zone of the next drum (the distance between the axes of the drums) or the linear speeds of the drums depending on the linear speed of the pile drums and the change in the mass of the cotton pieces.

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