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Investigation of the Movement of Cotton Seeds along the Groove Formed on the Surface of the Grate in the Working Chamber of the Saw Fiber Separator

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Abstract: Currently, much attention is paid to increasing the output of value-added finished products, improving the cotton industry system based on the deep processing of cotton raw materials, lowering production costs and improving the quality of cotton products based on the re-equipment of cotton primary processing technology.

When solving these problems, increasing the efficiency of the ginning process by improving the working chamber of the gin is one of the important tasks.

Also, the main way to increase the efficiency of the saw gin is to increase the fiber content of the raw roller, accelerate the yield of bare seeds and a uniform decrease in its density.

Keywords: The efficiency, roller, chamber, ginneries, grid-irons, gins ДП -130, section, respectively, straight lines, productivity.

1. Introduction.

Currently, much attention is paid to increasing the output of value-added finished products, improving the cotton industry system based on the deep processing of cotton raw materials, lowering production costs and improving the quality of cotton products based on the re-equipment of cotton primary processing technology.

When solving these problems, increasing the efficiency of the ginning process by improving the working chamber of the gin is one of the important tasks.

Also, the main way to increase the efficiency of the saw gin is to increase the fiber content of the raw roller, accelerate the yield of bare seeds and a uniform decrease in its density[1-4].

The rib grate is one of the main parts of the working chamber of the saw gin. It serves as a free pass saw blades between the grates in the working chamber and the free output of the fibers engaged on the saw teeth after separation. Rib grite are made by casting of cast iron grade SCh-15-32.

Working surfaces, processed on special machines, are reduced to a certain shape. The surface of the grate is hardened by he For normal operation of the saw blades, the working surface of the grate should be smooth and not rough, the distance between the grates in the working area should be 3 ± 0.2 mm, and in the lower part 4.5-5 mm. at treatment[5-8].

The number of grid-irons in the grate is one more than the number of saws on the shaft, two narrow grid-irons are installed in two extreme positions, and the rest with a normal width are intermediate. At the ginneries during the work of saw gins ДП -130, the teeth of the saw cylinder, catching the fibers from the raw roller, pass between the grates and are separated from the seeds. The fibers hooked onto the saw teeth are separated by an air stream exiting the nozzle.

The surface of the grate of this gin is flat, the interaction of the raw roller and the saw cylinder is constant, the machine performance is low, energy consumption and damage are high.

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Taking into account the above, we have proposed a grate with a concave profile for the rapid removal of bare seeds from the working chamber.

This rib-grate makes it possible to reduce friction with a saw cylinder and a raw roller, as a result of reducing damage to the fiber and seeds, as well as reducing energy consumption, accelerating the exit of bare seeds from the working chamber [8-12].

2. Simulation of ginning seeds on the control rib-grate.

Suppose the grate outline consists of two circles and two straight lines. Cotton seeds move along the contour in the form of a stream. We assume that the thickness of the flow along the contour is constant and equal to h_0.

Let the initial grate contour be composed of an arc of a circle AB, its continuation of a straight line BC, then an arc of a circle CB and a straight line BE (Fig. 1).

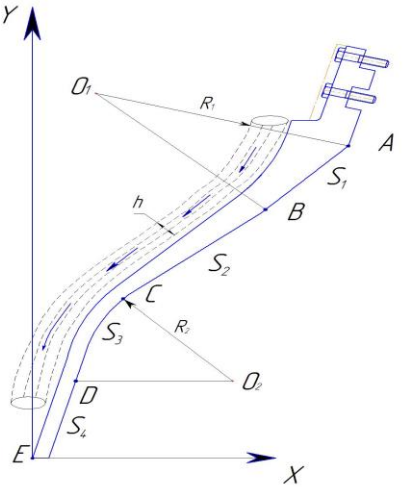

FIG. 1. The movement pattern of the flow of cotton seeds along the contour of the rib-grate. AB, CD - arcs of circles, BC, DE - straight lines.

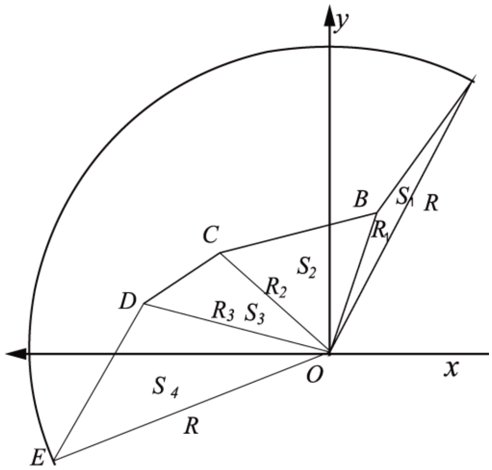

FIG. 2. The calculated contour of the rib-grate

We compose a unique equation of the flow in each section of the circuit. To determine the state of the flow, we denote its velocity, density and pressure in each section, respectively,

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$(v_1, \rho_1, P_1), (v_2, \rho_2, P_2), (v_3, \rho_3, P_3), (v_4, \rho_4, P_4)$. Let us determine the flow motion along the contour with respect to the arc. We calculate the length of each arc from point A and let the length of each section consist of $0 < s < s_a$ (section AB), $s_{01} < s_0 + s_1$ (section BC), $s_0 + s_1 < s_0 + s_1 + s_{02}$ (section CB) and $s_{01} + s_1 + s_0 < s < s_{01} + s_1 + s_0 + s_2$ (section DE). We write the Euler equation for each section:

$$\rho_1 v_1 \frac{\partial v_1}{\partial s} = -\frac{\partial p_1}{\partial s} + \rho_1 g[\sin(\alpha_{00} + s/R) + f\cos(\alpha_{00} + s/R)] - f\rho_1 \frac{v_1^2}{R_1} \quad (1)$$

$$0 < s < s_{01}$$

$$\rho_2 v_2 \frac{\partial v_2}{\partial s} = -\frac{\partial p_2}{\partial s} + \rho_2 g[\sin(\alpha_{00} + \alpha_{01}) - f\cos(\alpha_{00} + \alpha_{02})] \quad (2)$$

$$s_{01} < s < s_{01} + s_1 \ ,$$

$$\rho_3 v_3 \frac{\partial v_3}{\partial s} = -\frac{\partial p_3}{\partial s} + \rho_3 g[\sin(\alpha_{00} + s/R - s_1/R) - f\cos(\alpha_{00} + s/R - s_1/R)] - f\frac{v_3^2}{R_2} \quad (3)$$

$$s_{01} + s_1 < s < s_{01} + s_1 + s_{02}$$

$$\rho_4 v_4 \frac{\partial v_4}{\partial s} = -\frac{\partial p_4}{\partial s} + \rho_4 g[\sin \alpha_{00} + \alpha_{01} + \alpha_{02}) - f\cos(\alpha_{00} + \alpha_{01} + \alpha_{02})] \quad (4)$$

$$s_{01} + s_1 + s_{02} < s < s_{01} + s_1 + s_{02} + s_2$$

Here, f - is the coefficient of friction between the flow and the rib-grate, R_1, R_2 -are the radii of the circles.

The coordinate origin is set at point E, the axis ox is directed to the right, the axis oy is directed up.

The coordinates of points A, B, C, D and E, the angles α_{01}, α_{02}, as well as the radii R1 and R2 have a certain value, for equation (1) - (4) the lengths are determined by the following formulas.

$$s_{01} = \alpha_{01} R_1 \ , s_1 = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \ , s_{02} = \alpha_{02} R_2 \ , s_2 = \sqrt{(x_2 - x_3)^2 + (y_3 - y_2)^2}$$

In equations (1) - (4), three unknowns participate P_i, ρ_i, v_i, i = 1, 2, 3, to describe them in relation to one unknown, more precisely in relation to k v_i, we use these two conditions:

The flow is stationary, then the following condition must be fulfilled

$$\rho_i \cdot v_i \cdot h \cdot L = Q_0 \quad (5)$$

Here, Q-is the productivity of one grate for seed flow, L is the width of the grate.

From equation (5) we express the density in terms of speed:

$$\rho_i = \frac{Q_0}{v_i \cdot h_i \cdot L} \quad (6)$$

2. We accept the seed flow as a conjugate medium; therefore, the equation of state of the medium will be appropriate.

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$$\rho_i = \rho_0[1 + A(p_i - p_0)] \qquad (7)$$

Here, ρ_0, p_0 -is the density and pressure in the stream before feeding to the grate; A - experimentally determined physical quantity inversely proportional to the stiffness of the medium consisting of the mass of seeds.

To determine the flux density before feeding, we define the volume between any grates and two gear discs adjacent to them.

In accordance with FIG. 2, this volume is calculated by the following formula.

$$V = (\pi\beta R^2/2 - (S_1 + S_2 + S_3 + S_4)]L$$

Here, S- the area of the triangle.

$$S_1 = 0.5AB\sin\beta_1,\ S_2 = 0.5BC\sin\beta_2,\ S_3 = 0.5CD\sin\beta_3,\ S_4 = 0.5DE\sin\beta_4,$$

$$\beta_1 = \arccos\sqrt{\frac{R^2 + R_1^2 - AB^2}{R_1 R}},\ \beta_2 = \arccos\sqrt{\frac{R_2^2 + R_1^2 - BC^2}{R_1 R_2}},\ \beta_3 = \arccos\sqrt{\frac{R_3^2 + R_2^2 - CD^2}{R_2 R_3}},$$

$$\beta_4 = \arccos\sqrt{\frac{R^2 + R_3^2 - DE^2}{R_3 R}},\ \beta = \beta_1 + \beta_2 + \beta_3 + \beta_4$$

In the calculations we take, $AB = s_{01}$, $BC = s_1$, $CD = s_{02}$, $DE = s_2$

Let's say the volume V is completely filled with seeds of pieces with the same mass m.

Then the total mass of the volume is $M = N \cdot m$, and its density can approximately be calculated by the following formula.

$$\rho_0 \approx N \cdot m / V$$

Using formula (7) we find the relationship between pressure and density.

$$v_i = \frac{Q_0}{\rho_0 h_i L[1 + A(p_i - p_0)]} \qquad (8)$$

From equation (8) we determine the derivative $\frac{\partial p_i}{\partial s}$

$$\frac{\partial p_i}{\partial s} = -\frac{v_0}{v_i^2 A}\frac{\partial v_i}{\partial s} \qquad (9)$$

Using formulas (6) and (9), equations (1) - (4) lead to the following forms with respect to velocities v_i.

$$\frac{\partial v_1}{\partial s} = \frac{g v_1}{(v_1^2 - c^2)}(\sin\frac{s}{R_1} + f\cos\frac{s}{R_1}) - f\frac{v_1^3}{v_1^2 - c^2}\frac{1}{R_1} \qquad s_{00} < s < s_{01} \qquad (10)$$

$$\frac{\partial v_2}{\partial s} = \frac{g v_2}{(v_2^2 - c^2)}(\sin s_{01}/R - f\cos s_{01}/R) \qquad s_{01} < s < s_{01} < +s_1 \qquad (11)$$

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$$\frac{\partial v_3}{\partial s}=\frac{gv_3}{(v_3^2-c^2)v_3}(\sin\frac{s}{R_2}-f\cos\frac{s}{R_2})-f\frac{v_3^3}{v_3^2-c^2}\frac{1}{R}\qquad s_{01}+s_1<s<s_{01}+s_1+s_{02} \tag{12}$$

$$\frac{\partial v_4}{\partial s}=\frac{gv_4}{(v_4^2-c^2)v_4}(\sin s_{02}/R-f\cos s_{02}/R)\qquad s_{01}+s_1+s_{02}<s<s_0+s_1+s_0+s_2 \tag{13}$$

Here, $c=\sqrt{1/A\rho_0}$

Equations (10) - (13) are nonlinear, we integrate numerically under the following conditions:

$$v_1=v_{10} \text{ at } s=s_{00} \tag{14}$$

$$v_2(s_{01})=v_1(s_{01}) \text{ at } s=s_{01} \tag{15}$$

$$v_3(s_1+s_{01})=v_2(s_1+s_0) \text{ at } s=s_1+s_{01} \tag{16}$$

$$v_4(s_1+s_{01}+s_{02})=v_3(s_1+s_{01}+s_{02})$$

at

$$s=s_1+s_{01}+s_{02} \tag{17}$$

3. Analysis of the model for various values of the parameters of the rib-grate.

The following values are accepted in the calculations

$$L=0{,}16\quad R_1=0{,}107\quad R_2=0{,}1145\quad s_{01}=0{,}07098120639\quad s_1=0{,}07098120639$$

$$s_2=0{,}07604794422\quad s_3=0{,}07266443270\quad s_4=0{,}082050115661\quad s_0=0{,}3017437399$$

$$L=0{,}00818\,м,\ \mathrm{m}=0{,}025\cdot10^{-3}\,кг\quad N=250,\ f=0.2$$

As a result, the following results were obtained, in FIG. 2 shows the calculated contour of the rib-grate.

$$\beta_1=\alpha_1=0{,}3628444444\quad \alpha_2=0{,}6977777778\quad \alpha_3=0{,}5378122222\quad \alpha_4=0{,}2485833333$$

$$\alpha_0=1{,}847017777$$

$$\beta=\alpha_0=105{,}8799999\quad v=0{,}00007972317841\,м^3\quad \rho_0=31.35850890\ кг/м^3$$

In Figures 3 and 4 show plots of the distribution of the flow rate of the mass of seeds along the contour for various values of the angle and parameter, indicating its mechanical properties.

It can be seen from the graph that the flow velocity along the circuit is close to a linear regularity, and with increasing parameter A, the flow velocity decreases upon exiting the circuit. It is also seen that with increasing angle β_4 practically does not affect the distribution of speed.

$A=0.001Па^{-1}$ $A=0.005Па^{-1}$ $\beta_4=50^0$

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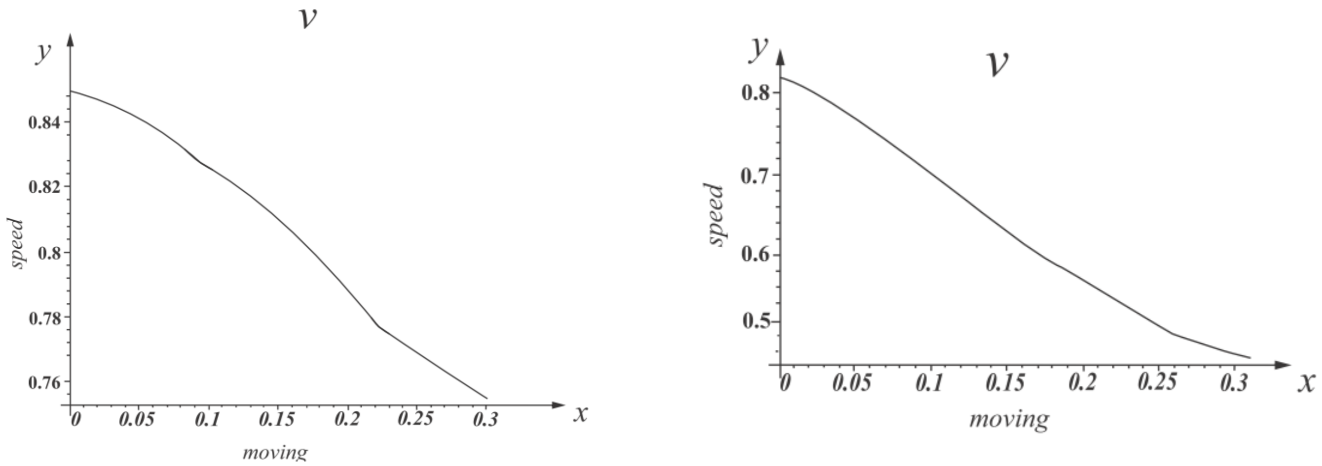
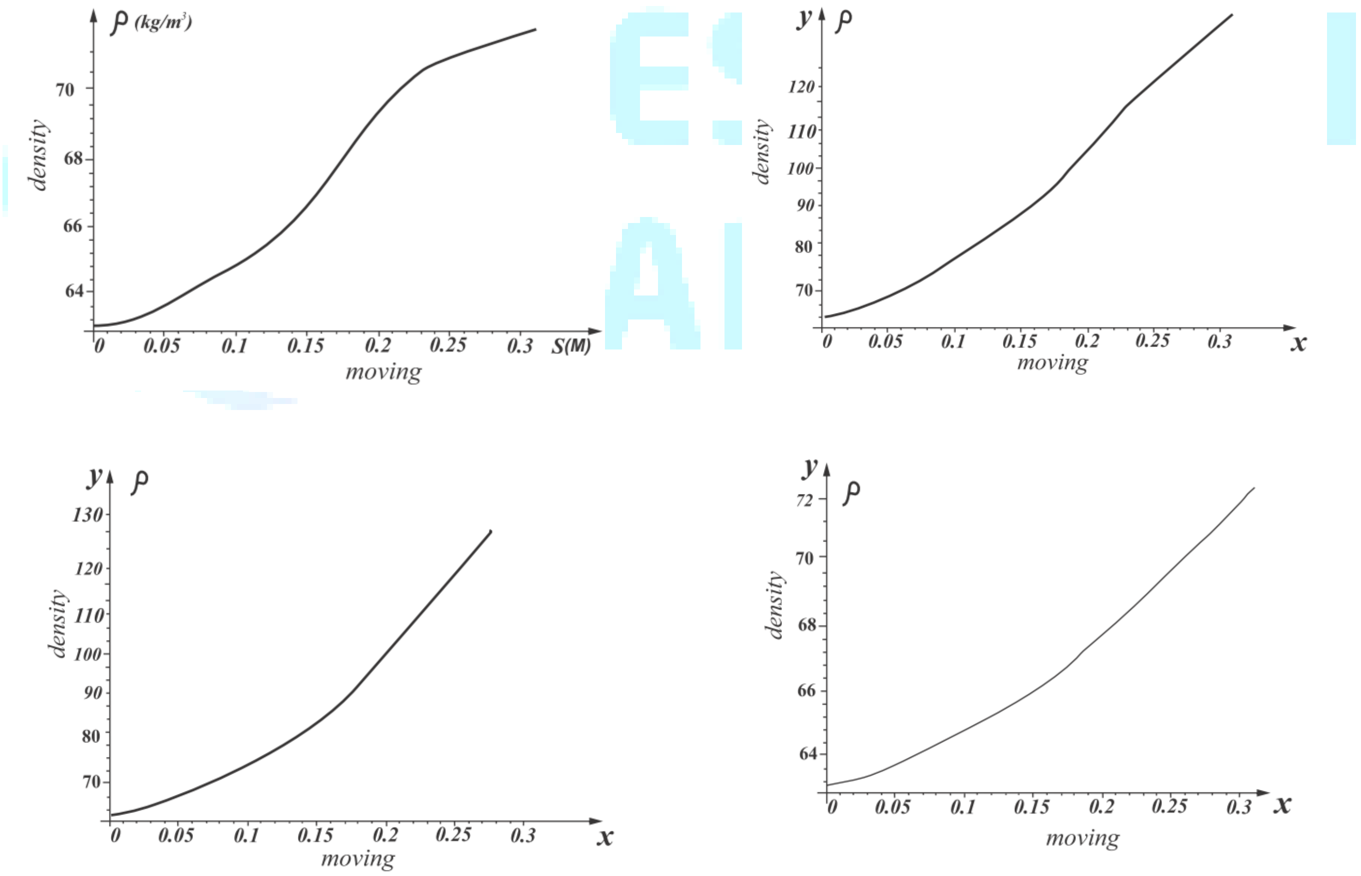


FIG. 3. Graphs of the distribution of seed flow velocity along the contour for two values of the angle β_4 and parameter A.

$A = 0.001 \Pi a^{-1}$ $A = 0.005 \Pi a^{-1}$ $\beta_4 = 50^0$



$\beta_4 = 80^0$

FIG. 4. Graphs of the density distribution ρ (kg / m^3) of the seed flow along the contour for two values of the angle and parameter.

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The parameter can significantly affect the change in flux density (Fig. 4) and with its increase, an increase in density, the formation of the mass of compacted seeds on the grate circuit is possible [12-14].

4. FINDINGS

1. A grate model consisting of four geometric forms is proposed, an analytical analysis of geometric types is presented. The dependence of the location of the last rectilinear part of the contour of the general contour on the shape of its convexity and concavity is determined.
2. A system of differential equations has been obtained to determine the law of the distribution of seed flow velocity along the contours of the proposed grate, using the law of conservation of mass and the equation of state of the medium. From the analysis of the law of the distribution of flow velocities, we observed the proximity of its distribution along the contour to a straight line, as well as a decrease in velocity along the contour.
3. The regularity of increasing the density of seed flow along the contour was determined, the possibility of increasing the density with increasing parameter (that is, with decreasing rigidity of the medium of the mass of seeds) was observed. This shows the probability of the formation of a high degree of density on the contour of the grate and in some cases the appearance of fixed zones of the medium.

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