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Mathematical Model of Cotton Extraction from Smooth Cotton Seeds

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ABSTRACT. This article investigates the mechanics of separation of fibers from the seeds in a straight-line separator. This process is determined by the law of coupling between the fiber mass and the force acting on it, and the angle of inclination of the fibers attached to the seeds is determined by the law of dependence of the distance between the rolls.

KEYWORDS: straight-flow fiber separator, fiber mass, roller surface, surface, contact environment, cotton fiber, cotton fiber, cotton fiber, elastic deformation, Winkler-Foyt law, shear strength, tension.

I. INTRODUCTION

Cotton production and the positive sale of its fiber in the world market are among the pressing issues. The production of high quality fiber that meets international standards puts the specialists and scholars of the cotton industry an important task, such as improving the existing techniques and technologies, and saving energy. One of the main tasks of the cotton processing enterprises, such as the quality of production of cotton fiber, is carried out by the cotton ginning equipment. Earlier scientific studies have shown that after the cottonseed weeding process, seeds and fibers are mechanically damaged, increasing the amount of contaminants in the raw material and the proportion of short fibers. Also high raw material density is 420-450 kg / m^3 [1]. Due to the fact that cotton fibers are interconnected and broken, a certain amount of seeds are crushed and broken, and their joining to the fiber affects the further technological processes. As *a* result of research conducted by the authors to solve this problem, the Republic of Uzbekistan in the newly proposed straight-line fiber separation equipment. The Intellectual Property Agency has received a positive response to the invention. Experimental version of the proposed device was prepared, which included preliminary tests and statistical analysis.

Exampleipg. We accept the following prerequisites for theoretical study of the process of separation of fiber from individual seeds:

1. Mass of fibers separated from seeds is considered as adjacent environment;
2. In the separation zone of the cotton fiber, the cylindrical surface is in contact with the separation element (rollers);
3. In the case of fissure deformation, there is a law of binding between tensile strength (tension) and deformation;
4. The forces between the spindles and the separation seeds are subject to the Winkler-Foigt initial displacement, and the large displacement to the Coulomb friction law;
5. The process of separation of fibrous masses from the surface of the seeds is carried out in one-dimensional direction.

Based on the above hypotheses, the mechanism of fiber extraction can be explained as follows. It takes some effort to pull the fibers from the seeds. The strength of this discontinuity should be determined experimentally. This force is usually reflected in the theory of coupling environments in the law of coupling (or deformation) of the fiber (or a group of fibers) and the force acting on it. Typically, such a link between the bonding environment (consisting of) of the stack of fibers and the tensile force (tension force) must be determined so that the handle is fully separated from the seeds. The cross-sectional surface of the handle must be constant and the stretching force evenly distributed on the shear surface. Under these conditions, the tensile strength of the shear surface is determined by $\sigma = T/S$(T-force), S-shear

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surface, $\varepsilon_0 = \frac{l_0 - l}{l}$ deformation of the elongation, l_0 – the initial length of the handle, Ee is called voltage deformation. This bond is widely used in determining the mechanical properties of materials.

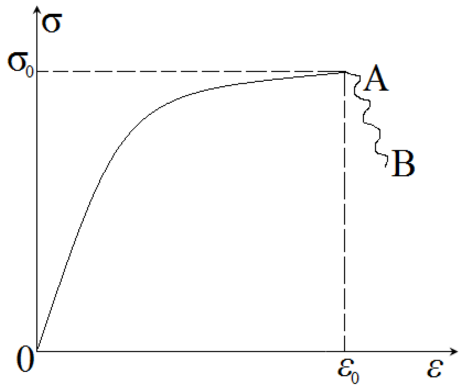

Figure 1. Scheme of fiber deformation

In most cases, this bond is linear and is denoted *by* $\sigma = E\varepsilon$. Here E - Yung module, in the theory of threads, this bond is defined by $T = E_1\varepsilon$. Then E_1 is considered as the elastic modulus.

The following link between E and E_1 is known as $E = E_1/S$.. During the separation of fibers, this bond is generally linear and denoted by $\sigma = E(\varepsilon)$. The peculiarity is that at the initial values of the bond, the bonding is weaker and later the resistance of the handle increases with increasing force, as the tensile strength increases, the resistance decreases as the fibers begin to break, and the deformation increases. Once the percentage of fibrous fiber reaches a certain value, the stalks can immediately dissolve the seeds. The same pattern can be seen in the extension of single strands. This process depends on the structural structure of the yarn, the disruption of the yarn depends on the structure, and the deformation of the yarn depends on the nature of the yarn formation.

Separation of the sap from the seeds surface in this case depends on the following factors:

The most important ones are:

a) Dependence on the moisture content, maturity, quality of raw materials in weed removal;

b) The force of separation depends on the position of the handle on the sap surface. Side separation strength is small and at the bottom and top of the seeds it should be relatively high.

c) The change in external tensile strength is time-dependent and, if the force is affected in the short term, the time for the stripping of the staple fibers to the surface is uneven. If the external force changes slowly over time, the separation may be flat over time, and the amount of fibers released will be lower. These laws do not fully explain the divorce process, but allow for a specific plan for experimentation. In order to fully understand the mechanism for removing cotton from seeds, it is necessary to use s pecial devices and instruments and measuring devices.

Method of solution. Based on the above hypotheses, we will theoretically study the mechanism of separation of fiber from the seeds. Figure 2 (a, b) shows the scheme for separating the fiber from individual seeds. As the cotton seeds are symmetrical on the surface of the rollers, look at the separation process for the right-hand roller. In practice, $R_2 = 4R_1$.

When the seeds are positioned against the roller, at t=0, a fiber-filled area is formed between them in the form of ABCDO; Once the amount of fiber separated has a critical value, the contact force between the seeds and the roller is freely separated from the rollers when the force of gravity decreases with the weight of the seeds.

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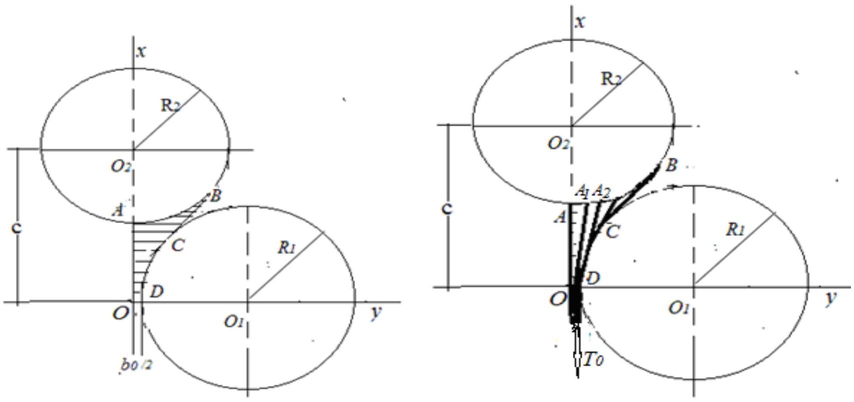
a) б)



The hypothesis of the aforementioned b) that the detachable fiber handle occupies the area ABCDO in Figure 2 b. The AA_1A_2B arc fibers are continuously attached to the seeds, and the bonded strength increases over time as the shaft pulls out, causing the fiber to break at *a* certain value. This power is distributed under a certain EU arc law, which is a key issue. Each fiber attached to the cotton seeds has an angle of inclination at the surface of the roll, so the tensile strength of the fiber depends on the angle of incision, according to Euler's formula. Let us take the arbitrary point from the AB arc and determine the bond strength between the fiber and the seeds in it with *T (, t)*. If we set the inclination angle *a*, this equation can be determined by equation. Here T_0 is the tensile strength of the roller out of the roller, the coefficient of friction between the fiber and the roller. We define the linear velocity and the rolling velocity in v_r, in the shear zone, v_e, take the relative velocity difference as time-dependent.We introduce the unit vectors on the contour arc and direct them to the strokes and normal values of the contour. The acceleration of the fiber attached at the optional point of the cutting curve is as follows: [1]:

$$\vec{\omega}=\vec{\omega}_e+\vec{\omega}_r=(\vec{\omega}_{e1}+\vec{\omega}_{r2})\vec{e}_2+(\vec{\omega}_{e1}+\vec{\omega}_{e2})\vec{e}_1$$

is here $\omega_{r1}=\dfrac{dv}{dt}=\dot{v}_r$, $\omega_{r2}=\dfrac{v_r^2}{dt}$, $\omega_{e1}=\dot{v}_e$, $\omega_{e2}=0$

τ ва q are denoted by the stroke and normal force (one unit length) between the fiber and the roller, then the equation of movement on the contour for the weightless fiber can be written as follows. [1]

$$\vec{e}_1\frac{\partial(T-\mu v_r^2)}{\partial s}+\frac{T-\mu v_r^2}{R}\vec{e}_2+\vec{\omega}_1-q\vec{e}_2-\mu\dot{v}_e\vec{e}_1=0 \qquad (1)$$

where - mass of the fiber. We assume that the fiber moves in the direction of the contour and we use these terms as $v_r>v_e$, $\tau=-fq$, $v_r<v_e$, $\tau=fq$, $v_r=v_e$, $-fN<\tau fN$, $v_r>v_e$ In equation (1) we can

$$\frac{\partial(T-\mu v_r^2)}{\partial s}-f(T-\mu v_r^2)=\mu R_2(\dot{v}_r+\dot{v}_e) \qquad (2)$$

$N=T-\mu v_r^2$ $\alpha<\varphi<\pi/2$ considered to be the point of contact of the fiber in the vertical direction with the roller, and $\varphi=\alpha$ deb as the point of separation of the fiber from the coil surface. We integrate equation (2) using the condition $T(\pi/2, t)=T_0$ (T_0fiber tension at output).

$$T=\left(T_0-\mu v_r^2+\frac{\mu R(\dot{v}_r+\dot{v}_e)}{f}\right)e^{f(\varphi-\pi/2_1)}-\frac{\mu R(\dot{v}_r+\dot{v}_e)}{f}+\mu v_r^2 \qquad (3)$$

$$N=\left(T_0-\mu v_r^2+\frac{\mu R(\dot{v}_r+\dot{v}_e)}{f}\right)e^{f(\varphi-\pi/2_1)}-\frac{\mu R(\dot{v}_r+\dot{v}_e)}{f} \qquad (4)$$

T_o determine the elasticity of the fiber it is necessary to determine the velocity and velocity.

The roller can rotate at a constant speed.Furthermore, when the fissure separation is constant (*a*-acceleration), the equations (3) and (4) appear as follows.

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$$T = \left(T_0 - \mu v_r^2 + \frac{\mu Ra)}{f} \right) e^{f(\varphi - \pi/2_1)} - \frac{\mu Ra}{f} + \mu v_r^2 \quad (5)$$

$$N = \left(T_0 - \mu v_r^2 + \frac{\mu Ra)}{f} \right) e^{f(\varphi - \pi/2_1)} - \frac{\mu Ra}{f} \quad (6)$$

In (5) and (6), the parameters α,α should be specified from the additional physical conditions. These terms are as follows.Consumption of fibers in the amount of seeds is determined by this formula when leaving the zone

$$Q = \rho_2 Sat , \quad (7)$$

where ρ_2, $S$is the density of the fiber leaving the zone and the cross-section of the fiber layer.If the fiber deformation is subject to Hook's law, then the deformation is $\varepsilon_0 = T_0 / ES$. (E - Yung module)

$$\frac{\rho_0}{\rho_{00}} = 1 - \frac{T_0}{ES} \quad (8)$$

bond (ρ_{00} is the natural density of the fiber). (8) Given the expression (7) we get the following.

$$Q = \rho_0 S (1 - \frac{T_0}{ES}) at$$

$t=t_0$, the amount of fiber falling out of the zone when the mass of the fiber attached to the seeds is completely separated

$$Q_0 = \rho_{00} S (1 - \frac{T_0}{ES}) at_0 \quad (9)$$

formula is determined by the formula. Q_0 ва $T_2$are known, then the acceleration a can be determined from formula (9)

$$a = \frac{Q_0}{\rho_{00} S (1 - \frac{T_0}{ES}) t_0} . \quad (10)$$

In the formula (3) α to determine the parameter, we determine the geometry of the fibers in the zone and the strength of the fiber attached to the seeds, in order to determine the parameter. If at any point in the circle, the distance between their centers is $R_1 + R_2$, and the distance between them is calculated by the following formula:

$$c = c_0 = (R_1 + R_2) \sin \alpha_{00} \quad (11)$$

where - is the angle of incidence expressed by this equation

$$\alpha_{00} = \arccos \frac{b_0 + R_2}{R_1 + R_2} \quad (12)$$

b_0 – the distance between the roller and the vertical axis. If the center of the shaft is moved vertically to the distance h, then c is defined as follows

$$c = c_0 + h = (R_1 + R_2) \sin \alpha_{00} + h . \quad (13)$$

The coordinates of points C and D are obtained by race 3:

$$\begin{aligned} x_c &= c - R_1 \sin \alpha_0 & y_c &= R_1 \cos \alpha_0 \\ x_D &= R_2 \sin \alpha_0 & y_D &= b_0 + R_2 - R_2 \cos \alpha_0 \end{aligned} \quad (14)$$

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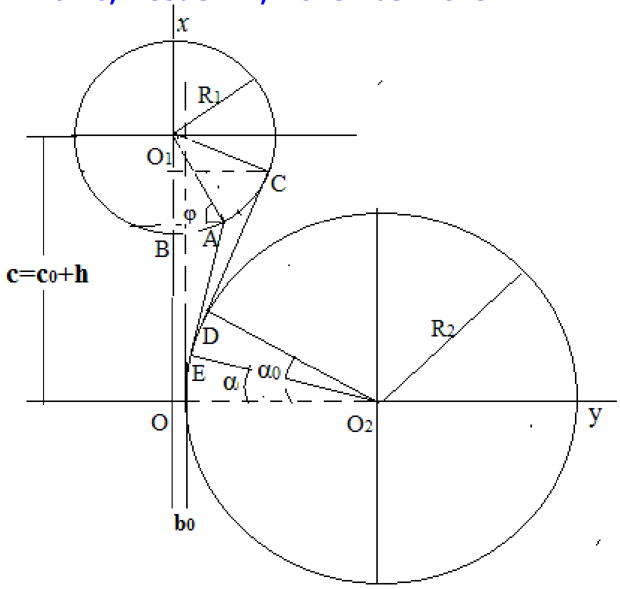

Figure 3. Geometry of the location of seeds and roller

The angle of incision is expressed by the following equation:

$$tg\alpha_0 = \frac{\sin\alpha_0}{\cos\alpha_0} = \frac{y_D - y_c}{x_D - x_c} = \frac{b_0 + R_2 - R_2\cos\alpha_0 - R_1\cos\alpha_0}{R_2\sin\alpha_0 - c + R_1\sin\alpha_0}. \quad (15)$$

We derive the equation of expression from (15)

$$[b_0 + R_2 - (R_1 + R_2)\cos\alpha_0]\cos\alpha_0 + [(R_2 + R_2)\sin\alpha - c]\sin\alpha_0 + (b_0 + R_2)\cos\alpha_0 + c\sin\alpha_0 = R_1 + R_2. \quad (16)$$

The solution to this equation (16) is as follows

$$\alpha_0 = \gamma - \beta \quad (17)$$

Is here $\gamma = \arcsin\frac{R_1 + R_2}{\sqrt{(b_0 + R_2)^2 + c^2}}$; $\beta = \arcsin\frac{b_0 + R_2}{\sqrt{(b_0 + R_2)^2 + c^2}}$.

II. ANALYSIS OF RESULTS.

Figure α_0 shows graphs of the variation of the angle with respect to *h* at different values of distance b_0. The following values are accepted in the calculation: $R_2 = 0.0055\text{м}$, $R_1 = 0.02\text{м}$ $b_0 = 0.002 \div 0.003\text{мм}$, $R_1 \approx 4R_2$. $R_2 = 0.005\text{м}$

From the graph analysis, the inclination angle decreases as the distance between the seeds and roller *h* and the rollers increases b_0. Also increasing the distance b_0 will result in a sharp reduction in the angle of coverage.

Now we find that when the optional point *A* is removed on the surface of the seeds, the fiber angle of the fiber changes. Determine the coordinates of the point *D*, which is an *A* and a circle to the circuit.

According to Figure 3

$$x_A = c - R_1\sin\varphi, \qquad y_A = R_1\cos\varphi,$$
$$x_D = R_2\sin\alpha, \qquad y_D = b_0 + R_2 - R_2\cos\alpha. \quad (18)$$

The inclination angle satisfies this equation

$$tg\alpha_0 = \frac{\sin\alpha_0}{\cos\alpha_0} = \frac{y_A - y_D}{x_A - x_D} = \frac{R_1\cos\varphi - b_0 - R_2 + R_2\cos}{c - R_1\sin\varphi - R_2\sin\alpha}. \quad (19)$$

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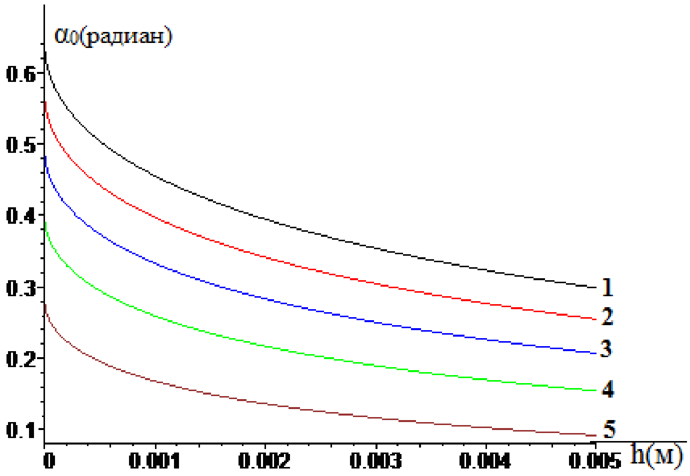

Figure 4. Graphs of the maximum inclination angle (radian) between the center of the circle at different values of the distance between the roller and the vertical axis

-$1-b_0=0,\ 2-b_0=0.001,\ 3-b_0=0.002,\ 4-b_0=0.003,\ 5-b_0=0.004$

We derive the equation of expression from (19)

$$(R_1\cos\varphi+R_2\cos\alpha-b_0-R_2)\cos a=(c-R_1\sin\varphi-R_2\sin a)\sin a$$
$$R_1(\cos\varphi\cos a+\sin\varphi\sin a)+R_2-(b_0+R_2)\cos a-c\sin a=0 \quad (20)$$

We derive this equation (20) as follows:

$$(c_1-R_1\sin\varphi)\sin a+(b_0+R_2-R_1\cos\varphi)\cos a=R_2 \quad (21)$$

In this equation, we define the expression through the angle

$$\alpha=\gamma(\varphi)-\beta(\varphi), \quad (22)$$

Is here $\gamma(\varphi)=\arcsin\dfrac{R_2}{\sqrt{(c-R_1\sin\varphi)^2+(b_0+R_2-R_1\cos\varphi)^2}}$,

$$\beta(\varphi)=\arcsin\frac{b_0+R_2-R_1\cos\varphi}{\sqrt{(c-R_1\sin\varphi)^2+(b_0+R_2-R_1\cos\varphi)^2}}.$$

In equation (22), we find that the change of the angle of the fiber change when the optional point *A* on the surface of the seeds is obtained.

The graphs of variation in the two values (*rad*) of the angle of inclination are shown in Figure 5. As the distance from the graphs analysis increases, the angle of incidence decreases and the range of angles that can be determined is also reduced.

$h=0.002$м, $b_0=0$ $\qquad$ $h=0.002$м, $b_0=0.002$м

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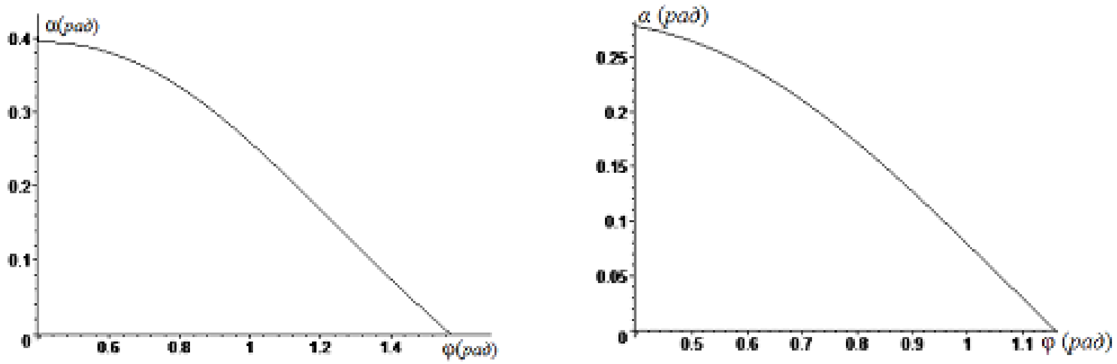

Figure 5. Graphs of variation with respect to angles at different values in the case of variable inclination angles.

Figure 6 shows the relative elasticity of the fiber using the formula (5) to determine the force acting on the seeds when the shear angle and acceleration are known. From the graph analysis, there is a partial reduction in tension with increasing angle and distance

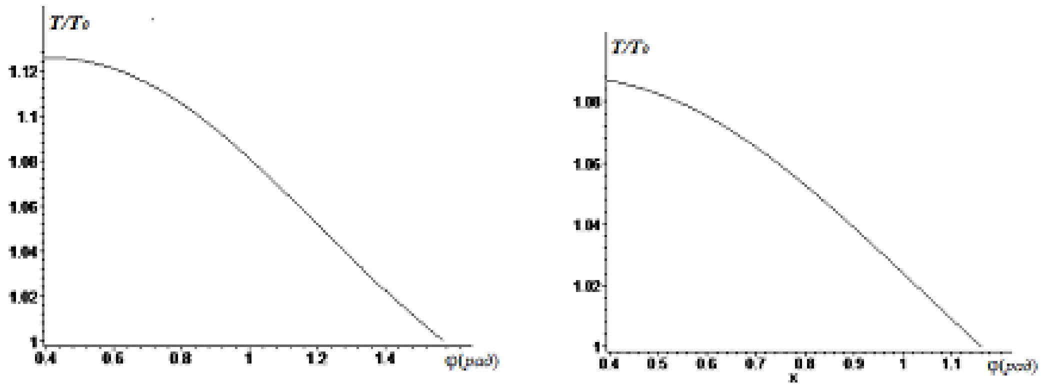

Figure 6. Variation of fibers with different values of angle of inclination relative to angle.

CONCLUSION

1. Increasing the distance b0 between the horizontal axis and the shaft and the vertical axis causes a sharp decrease in the angle of incision.

2. Increasing the distance between the vertical axis and the roller is observed to decrease the invertebrate displacement angle

3. It has been observed that increasing the distance between the rollers in the process of separating the fiber from the cotton seeds causes a decrease in the tensile strength of the fibers.

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