Research of the reasons of increased drop in cotton seeds after generation with reduced density of raw roller

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Abstract. Results of researches on definition of influence of density of the raw roller on pubescence of cotton seeds are given in article. The received mathematical model for calculation of contact pressure and movement of the raw roller in the form of a system from six equations with six unknown. The numerical results calculated on the computer. Sizes of shift and contact pressure for the set physic-mechanical and geometrical parameters of a system are determined. It is established that contact pressure significantly depends on elasticity (density) and angular speed of the raw roller. On the basis of the graphic data of contact pressure and contact movement of the raw roller received results of calculations the conclusion that with reduction of density of the raw roller conditions of capture of a short cotton slice worsen. The fact that the contact pressure and movement fluctuate during time is the reason of it, i.e. in the beginning the short cotton slice contacts to a saw, but during fractions of a second this contact is lost, also contact pressure similarly changes. Results of theoretical researches proved increase in a full pubescence of seeds after gin with reduction of density of the raw roller, i.e. one of the reasons of it is deterioration in conditions of capture of short cotton slices a saw - fluctuations of contact pressure and contact movement of the raw roller.

1. Introduction
The strategy of actions for the further development of the Republic of Uzbekistan for 2017-2021 provides for "Increasing the competitiveness of the
national economy, reducing energy and material costs in the economy, widespread introduction of energy-saving technologies into production" [1].

One of the main ways to increase production efficiency is the technical re-equipment of the industry's enterprises, with the introduction of the latest achievements of science and technology into production [2].

The layout of the working chamber and working bodies of the currently produced gins of the DP-130 series determines the formation of a high-density raw roll, which causes large dynamic loads on the produced fiber and raw cotton seeds. This leads to increased damage to seeds, an increase in fiber defects and fiber losses due to the bottoming of the upper zone of the grate, high energy consumption for the rotation of the raw roller. In addition, spun fiber is lost with undegenerated seeds coming out of the working chamber with increased pubescence [3].

The study of previously conducted research in the field of saw ginning shows that there are enough works aimed at studying the working chamber of the saw gin, but they were carried out mainly in one direction - increasing the volume of the working chamber. These works were aimed at increasing the productivity of gin by increasing the density of the raw roll [4].

There are very few studies on the effect of the seed comb on the performance of the saw ginning process. There are practically no theoretical works on the study of the capture of fibers by saws in the area of the seed comb. Previous studies have established that with a decrease in the density of the raw roll, the quality of fiber and a seed improves the productivity of gin increases, the energy consumption decreases, but at the same time the pubescence of the seeds increases [5, 6].

The question arises as to how a decrease in the density of the raw roller will affect the process of picking up the fibers by the saw teeth. This question can be answered only after a theoretical and experimental study of the effect of a decrease in the density of a raw roller on the process of grabbing fibers by saw teeth. In order to determine the cause of this phenomenon, these studies were conducted [7, 8].

The development of a mathematical model of the process is an urgent task in this work. It is suggested that a cotton fly is considered as a deformable heterogeneous body. In the first step, a cotton particle is modeled as a material particle surrounded by massless viscoelastic elements [9].

Also, the fly is modeled as a system of material points connected to viscoelastic-plastic elements. The problems posed are solved in an exact as well as an approximate setting with specific boundary and initial conditions. As a first approximation, we will consider the motion of a raw roller without friction relative to the position of static equilibrium.

2. Methods

For a start we will define the equation of balance which has an appearance:
\[ r \frac{\partial \sigma_r}{\partial r} + \sigma_r - \sigma_\theta + \rho r^2 \omega^2 = 0 \]  

(1)

where \( \rho \) - the mass density of viscoelastic material - the raw roller, \( \omega = \omega(t) \) - angular speed of rotation. If to designate the main deformations through \( \varepsilon_r, \varepsilon_\theta \) and \( \varepsilon_z \), radial movement - through \( u \), at flat deformation we have:

\[ \varepsilon_r = \frac{\partial u}{\partial r}, \quad \varepsilon_\theta = \frac{u}{r}, \quad \varepsilon_z = 0 \]  

(2)

For simplification of calculations, in view of lack of contradictory experimental data for the majority of viscoelastic materials, it is supposed that material behaves it is elastic at volume expansion, has volume model \( K \) and is viscoelastic in relation to shift. If the body was in not indignant state till the moment \( t = 0 \), that the defining equations are given to a look

\[ \sigma_r + \sigma_\theta + \sigma_z = 3k \left( \frac{\partial u}{\partial r} + \frac{u}{r} \right) \]

\[ \sigma_\theta - \sigma_r = 2 \int_0^t G(t-\tau) \frac{\partial}{\partial \tau} (\varepsilon_\theta - \varepsilon_r) d\tau = 2 \int_0^t G(t-\tau) \frac{\partial}{\partial \tau} \left( \frac{u}{r} - \frac{\partial u}{\partial r} \right) d\tau, \]

\[ \sigma_z - \sigma_r = 2 \int_0^t G(t-\tau) d\tau = 2 \int_0^t G(t-\tau) \frac{\partial u}{\partial r} d\tau \]  

(3)

Boundary conditions which should satisfy to external pulse tension:

\[ \sigma_r[0(t), t] = -p(t) \]  

(4)

to internal border:

\[ U_r[0(b), t] = 0 \]  

(5)

Four equations (1-4) serve for definition of four unknown: \( \sigma_r, \sigma_\theta, \sigma_z \) and \( \varepsilon_\theta \) (through \( u \)). However two boundary conditions support only two of them, \( \sigma_r \) and \( \varepsilon_\theta \), and therefore it is necessary to exclude \( \sigma_r \) and \( \sigma_z \) as it will be made below. Combining the equation (1-3), we receive

From here, using boundary conditions (6) and (7), we receive for \( \sigma_r(b, t) \) integrated equation of the second parcels sort

\[ \sigma_r(b, t) + \frac{2\mu}{E} \int_0^t G(t-\tau) \sigma_r(b, \tau) d\tau = \frac{\mu B}{E} \left[ \frac{1}{2} pr^2 \omega^2(t) - f(t) \right] \]  

(6)

where
\[ \mu = \frac{E}{2G(0) - \beta} \]  

To receive the second integrated equation for \( \sigma_r(b,t) \) and \( f(t) \) exclude in the beginning \( \sigma_r \) from the equations (7), then \( \sigma_B \) by means of the equation (4), at last, by means of (6), it gives

\[ 3\sigma_r - \frac{3K}{r} \frac{\partial}{\partial r} \left( r^2 \varepsilon_{\theta} \right) + 2 \int_0^r G(t - \tau) \frac{\partial}{\partial \tau} \left( \varepsilon_{\theta} + 2r \frac{\partial}{\partial r} \right) d\tau \]

(8)

The boundary condition containing \( \varepsilon_{\theta} \), it was already used, and enters another only \( \sigma_r \). Therefore in the equation (7) the members containing \( \varepsilon_{\theta} \), are excluded by means of the equations (2) and (3) are replaced on \( \sigma_r \) and \( f(t) \). The member containing \( \varepsilon_{\theta} \) subintegral expression, it is excluded by addition of the equation (2) and doubling of the equation (1) that results taking into account (8) equality

\[ \Omega(r,t) = \frac{1}{2} f(t) - \frac{5}{4} p r^2 w^2 + \frac{3K}{2r} \frac{\partial}{\partial r} \left( r^2 \varepsilon_{\theta} \right) \]

(9)

where for convenience the designation is entered

\[ \Omega(r,t) = 2\sigma_r + r \frac{\partial}{\partial r} \left( r^2 \varepsilon_{\theta} \right) \]

Putting doubled (3) with the equation (2) it is received:

\[ \Omega(r,t) = 2 f(t) - 2 p r^2 w^2 (t) - \frac{2}{r} \int_0^r G(t - \tau) \frac{\partial^2}{\partial r^2} \left( r^2 \varepsilon_{\theta} \right) d\tau \]

and member \( \frac{\partial}{\partial r} \left( r^2 \varepsilon_{\theta} \right) \) it is excluded by means of the equation (9). As a result, we have:

\[ \Omega(r,t) + \frac{4}{3K} \int_0^r G(t - \tau) \frac{\partial Q(r,t)}{\partial \tau} d\tau = 2 f(t) - 2 p r^2 w^2 (t) - \frac{2}{r} \int_0^r G(t - \tau) \frac{\partial^2}{\partial r^2} \left( r^2 \varepsilon_{\theta} \right) d\tau + \frac{1}{3K} \int_0^r G(t - \tau) \frac{\partial}{\partial \tau} \left[ 2 f(t) - 5 p r^2 w^2 (t) \right] d\tau \]

(10)

As it was noted earlier, it is difficult to enter into consideration a boundary condition on the burning-out surface if function is not excluded \( R(t) \) determined by equality:
\[ R(t) + \frac{4}{3K} \int_0^t G(t-\tau) \frac{\partial R(\tau)}{\partial \tau} d\tau = 2G(t). \]

Using associative property of convolutions, we will rewrite the equation (10) in a look:

\[ \Omega(r,t) = \left[ 2 - \frac{R(0)}{K} \right] f(t) - pr^2 \omega^2(t) + \frac{1}{K} \int_0^t R(t-\tau) \frac{\partial}{\partial \tau} \left[ \frac{1}{2} pr^2 \omega^2(\tau) - f(\tau) \right] d\tau. \]

Gap exception at \( t = 0 \) integration is given in parts:

\[ \Omega(r,t) = \left[ 2 - \frac{R(0)}{K} \right] f(t) - \frac{R(0)}{2K} - \frac{1}{K} \int_0^t R'(t-\tau) f(\tau) d\tau + \frac{pr^2}{2K} \int_0^t R'(t-\tau) \omega^2(\tau) d\tau. \]

Considering (10), integrating the last equality on \( r \) and using a boundary condition (5), we receive:

\[ r^2 \sigma_r(r,t) = \frac{1}{2} \left[ r^2 - a^2(t) \right] \left[ 2 - \frac{R(0)}{K} \right] f(t) - \frac{1}{K} \int_0^t R'(t-\tau)f(\tau)d\tau - \frac{pr^2}{4} \left[ r^2 - a^2(t) \right] \left[ 2 - \frac{R(0)}{2K} \right] \omega^2(t) - \frac{1}{2K} \int_0^t R'(t-\tau) \omega^2(\tau) d\tau - a^2(t) p(t). \]

This equality takes place, in particular, at \( r = b \) and therefore:

\[ b^2 \sigma_b(b,t) = \frac{1}{2} \left[ b^2 - a^2(t) \right] \left[ 2 - \frac{R(0)}{K} \right] f(t) - \frac{1}{K} \int_0^t R'(t-\tau)f(\tau)d\tau - \frac{pr^2}{4} \left[ b^2 - a^2(t) \right] \left[ 2 - \frac{R(0)}{2K} \right] \omega^2(t) - \frac{1}{2K} \int_0^t R'(t-\tau) \omega^2(\tau) d\tau - a^2(t) p(t). \]

This integrated equation of type of convolution for \( f(t) \), which together with (10) forms the system of the integrated equations for unknown functions \( f(t) \) and \( \sigma_r(r,t) \). As it will be shown below, they can be solved in the numerical way of the joint solution of their representation in a final and differential form. As soon as function \( f(t) \) defined, \( \sigma_r(r,t) \) it is possible to receive from the equation (6) then their equation (10) from equality is defined:

\[ \sigma_r(r,t) = \Omega(r,t) - \sigma_r(r,t) + pr^2 \omega^2(t) \]

At last, \( \varepsilon_\theta(r,t) \) and \( u(r,t) \) it is possible to receive, solving the integrated
equation (5) at known $\sigma_r(r,t)$ and $f(t)$ or by means of the direct integrated representation which is turning out the address of the equation (4) which gives as:

$$\varepsilon_r(r,t) = \frac{1}{2} \int_0^t f(t' - r) \frac{\partial}{\partial t} \left[ \sigma_r(r,t) - \frac{1}{2} pr^2 \omega^2(r) \right] dt'. $$

At known $f(t)$ and $\sigma_r(r,t)$ this integral can be calculated directly having excluded previously a gap at $t = 0$. Function of creep $f(r)$ can be or it is measured as characteristic of material, or determined by value of the relaxation module in number $G(t)$, as it is shown in work [4-6].

3. Obtaining Numerical Results
For obtaining numerical results the following initial parameters were accepted:
Relaxation kernel: $f(t) = Ae^{-\beta t} \cdot t^{a-1}$, $\nu = 0.3$, $E_0 = 100 - 200$ GPa; $G = 20$ MPa; $A = 0.01$; $\alpha = 0.1$, $\beta = 0.001$, $17$ kg/m$^3 < \rho < 500$ kg/m$^3$, and $125$ mm $< a(t) < 250$ mm. Settlement scheme of contact pressure of the raw roller upon a saw is given in Figure 1. In Figure 2-4, the main settlement schemes and the geometrical amount of contact are provided.

![Diagram](image.png)

**Fig. 1.** Settlement scheme of contact pressure of the raw roller upon a saw
Change of contact pressure depending on time (resonant case) at periodic influences of external loadings is given in Figure 5. Results of movement depending on time (Figure 6 and 7). Similar results are received for non-resonance (Figure 8) the change of contact pressure in a case is given. In Figure 9, the change of contact pressure depending on time in non-stationary interactions is represented. In the following drawing of dependence on time taking into account relaxation properties of cotton-raw.
Figure 6. Change of contact movement depending on time (Resonant case)

Figure 7. Change of contact pressure depending on time (Non-resonance case)

Figure 8. Change of contact pressure depending on time at non-stationary interactions
Figure 9. Change of contact pressure depending on time taking into account relaxation properties of cotton-raw

On the basis of the graphic data of contact pressure and contact movement of the raw roller received by results of calculations it is possible to draw a conclusion that with reduction of density of the raw roller conditions of capture of a short cotton slice worsen. The fact that contact pressure and movements fluctuate during time is the reason of it, i.e. in the beginning the short cotton slice contacts to a saw, but during fractions of a second this contact is lost, also contact pressure similarly changes [10].

It is possible to prove by results of theoretical researches increase in a full pubescence of seeds after gin with reduction of density of the raw roller, i.e. one of the reasons of it is deterioration in conditions of capture of short cotton slices a saw - fluctuations of contact pressure and contact movement of the raw roller.

4. Conclusions

a) On the basis of the theory of mechanics of the deformed solid body the method for determining change of a condition of the raw roller is developed in interaction with a saw cylinder of gin.

b) The mathematical model for calculation of contact pressure and movement of the raw roller in the form of a system from six equations with six unknown is received.

c) Programs for the solution of the received mathematical model on the computer are developed and made.

d) Numerical results on the computer are received. Sizes of shift and contact pressure for the set physic-mechanical and geometrical parameters of a system are determined. It is established that contact pressure significantly depends on elasticity (density) and angular speed of the raw roller.
e) On the basis of the graphic data of contact pressure and contact movement of the raw roller received by results of calculations it is possible to draw a conclusion that with reduction of density of the raw roller conditions of capture of short cotton slice worsen. The fact that the contact pressure and movement fluctuate during time is the reason of it, i.e. in the beginning the short cotton slice contacts to a saw, but during fractions of a second this contact is lost, also contact pressure similarly changes.

f) It is possible to prove by results of theoretical researches increase in a full pubescence of seeds after gin with reduction of density of the raw roller, i.e. one of the reasons of it is deterioration in conditions of capture of short cotton slices a saw - fluctuations of contact pressure and contact movement of the raw roller.

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