RESEARCH ARTICLE

INVESTIGATION OF THE INTERACTION OF THE ROLLER AND THE STATIONARY KNIFE OF THE ROLLER GIN WITH COTTON FIBER

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Manuscript Info	Abstract
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The work is devoted to one of the topical issues of the cotton ginning industry. The article discusses the dynamic and mathematical models of the process in the interaction of the "working drum-stationary knife" system with the fiber of the ginned fly and solutions are given that allow you to determine the necessary part of the surface of the working drum and knife, taking into account the dynamics of the system. This method of solving problems is relevant because leads to the intensification of the roller ginning process.

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Introduction:-

It is known that, [1, 2], in order to increase the efficiency of roller ginning and productivity of gin, it is necessary to more actively use the instant friction area of the working drum (roller). The completeness of the use of the friction area of the drum depends on the rational and uniform use of the entire length of the contact of the stationary knife with the working drum, as well as on the duration of ginning of each fly (flying fibre). The process of pulling bundles of fibers of the fly along the length of the knife is random and depends on the uniformity of the supply, the reliability of the capture of the fibers by the working drum and the duration of ginning of the individual fly [2, 3, 4]. In addition, cotton flies that enter the ginning zone are different in looseness, density, thickness and length [5, 6, 7]. As a result of the pulling of the fiber bundle by the working roller behind the stationary knife, the elastic system of the working drum and the knife receives additional deformation, different in the thickness of the bundle. This deformation causes an increase in pressure on the pulled fiber, which, on the one hand, leads to an increase in the tightening force and efficiency of ginning and, on the other hand, to possible damage to the fibers if the pressure exceeds the permissible value for cotton fibers (according to our data, 80-100 kg/cm^2).

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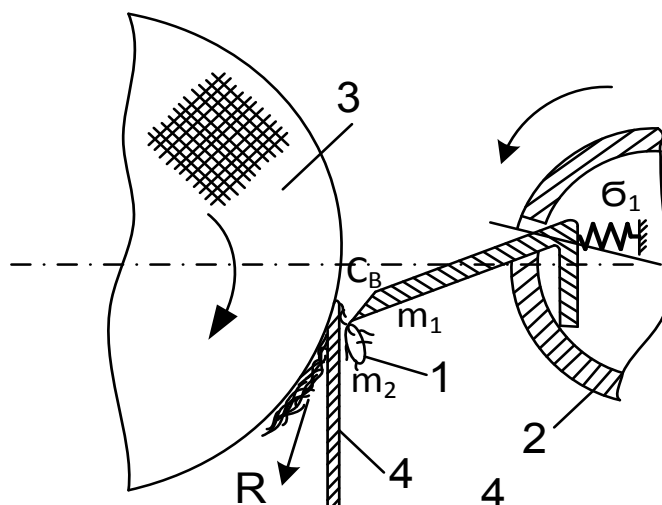
1-seed of the fly, 2-rotary knife drum, 3-working drum (roller), 4-stationary knife
Fig.1:- Model of the roller ginning process.

Theoretical analysis of the interaction of the working drum and stationery knife with cotton fiber.
Studies have shown that the deformation of the system under static conditions [2], the increase in pressure is determined by the rigidity parameters of the surface of the working drum and stationary knife. The permissible pressure of cotton fibers in the mass (in the form of a bundle of fibers) is the initial condition for the correct setting of the stiffness of the working drum and stationary knife.

However, in order to correctly estimate the actual values of the pressure increase, it is necessary to consider the elastic system not only in statics, but also in dynamics, since if the time of ginning coincides with the half-time of the natural oscillations of the system, a sharp increase in pressure is possible, i.e. it is necessary to approximately estimate the dynamic coefficient and find its dependence on the stiffness parameters of the system [7]. We will assume that the working drum - knife system is preloaded and the following conditions:

$$C_1 X_{01} = C_2 X_{02}; \tag{1}$$

Where, C_1 and C_2 are the hardness coefficients of the surface of the working drum and knife; X_{01} and X_{02} are preliminary deformations of the surface of the working drum and stationary knife when tuning the gin.

When a bundle of fibers is pulled in, the volatiles with a thickness of the static equations have the form

$$C_1 (X_{01} + \delta_{02}) = C_2 (X_{02} + \delta_2); \tag{2}$$
$$\delta_0 = \delta_1 + \delta_2; \tag{3}$$

Where, δ_1 and δ_2 are the increment in deformation of the surface of the working drum and knife. Thisimplies:

$$\delta_1 = \frac{\delta_0}{1 + \frac{C_1}{C_2}}; \delta_2 = \frac{\delta_0}{1 + \frac{C_2}{C_1}}; \tag{4}$$

Since the process of ginning individual volatiles (fly) is short-term and is measured in hundredths and thousandths of a second, it is of interest to study the elastic system in dynamics. Let's compose a dynamic model of the interaction process of the "working drum-stationary knife" system with the fiber of the ginned fly:

a)

b)
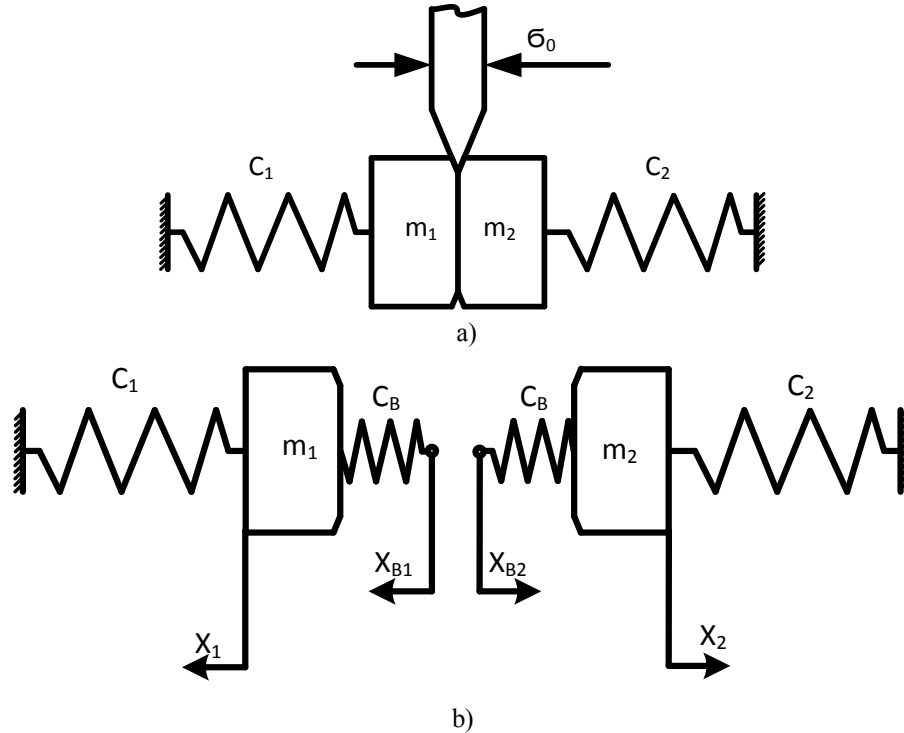
$X_v = f(t)$ - Kinematic disturbance from the pulled fiber;
X_1 and X_2 - coordinates of mass movement;
V_0-speed of the working drum; δ_0-thickness of the fiber bundle.

Fig.2:- Dynamic model of the process of interaction of a working drum and a knife with fiber

Where, m_1 is the mass of the working drum material brought to the interaction point; m_2 is the mass of the knife reduced to the point of interaction; C_1-hardness coefficient of the working drum surface; C_2- coefficient of hardness of the knife surface; S_f - stiffness coefficient of the fibers of the fly, pinched between the stationary knife and the working drum;

The mathematical model of the system under consideration, compiled using the Lagrange equation of the second kind, has the form as follow:

$$m_1\ddot{X}_1 = (X_{f1} - X_1)C_f - C_1(X_1 + X_{01}); \tag{5}$$
$$m_2\ddot{X}_2 = (X_{f2} - X_2)C_f - C_2(X_2 + X_{02}); \qquad \text{or}$$
$$m_1\ddot{X}_1 + (C_1 + C_f)X_1 = C_f X_{f1} - C_1 X_{01}; \tag{6}$$
$$m_2\ddot{X}_2 + (C_2 + C_f)X_2 = C_f X_{f2} - C_2 X_{02};$$

Where, $X_{в1}$ and $X_{в2}$ - kinematic disturbances from the pulled fiber.
For bundles of fibers pulled by the knife, we take linear dependences in the form of the following functions:

$$X_{f1} = \frac{tg\alpha}{1+\frac{c_1}{c_2}}V_0 t; \qquad X_{f2} = \frac{tg\alpha}{1+\frac{c_2}{c_1}}V_0 t; \tag{7}$$

Where, α is the wedge angle of the fiber bundle (can be determined experimentally).
Taking this into account, the mathematical model will have the following form:

$$m_1\ddot{X}_1 + (C_1 + C_f)X_1 = \frac{C_f tg\alpha}{1+\frac{C_1}{C_2}}V_0 t - C_1 X_{01}; \tag{8}$$

$$m_2\ddot{X}_2 + (C_2 + C_f)X_2 = \frac{C_f tg\alpha}{1 + \frac{C_2}{C_1}}V_0 t - C_2 X_{02};$$

Dividing both parts into m_1 and m_2, we get:

$$\ddot{X}_1 + \omega_{01}^2 X_1 = \frac{A_1}{m_1}V_0 t + \frac{B_1}{m_1}; \tag{9}$$

$$\ddot{X}_2 + \omega_{02}^2 X_2 = \frac{A_2}{m_2} V_0 t + \frac{B_2}{m_2};$$

Where ω_{01} and ω_{02} are the circular frequencies of natural vibrations of the working drum and stationary knife surface area:

$$\omega_{01} = \sqrt{\frac{C_1 + C_f}{m_1}} \; ; \; \omega_{02} = \sqrt{\frac{C_2 + C_f}{m_2}} \; ;$$

$$A_1 = \sqrt{\frac{C_\text{в} tg\alpha}{1 + \frac{C_1}{C_2}}} \; ; \; A_2 = \sqrt{\frac{C_\text{в} tg\alpha}{1 + \frac{C_2}{C_1}}} \; ;$$

$$B_1 = -C_1 X_{01} \; ; \; B_2 = -C_2 X_{02};$$

The general solution to the inhomogeneous equation (9) can be written as follows:

$$X_1 = D_1 \cos\omega_{01} t + E_{01} \sin\omega_{01} t + \frac{A_1 V_0}{C_1 + C_\text{в}} + \frac{B_1}{C_1 + C_\text{в}}; \qquad (10)$$

$$X_2 = D_2 \cos\omega_{02} t + E_{02} \sin\omega_{02} t + \frac{A_2 V_0}{C_2 + C_\text{в}} + \frac{B_2}{C_2 + C_\text{в}};$$

From the initial conditions $t = 0; X_1 = 0; \ddot{X} = 0;$

$$D_1 = -\frac{B_1}{C_1 + C_f}; \; E_1 = \frac{A_1 V_0}{C_1 + C_f} \sqrt{\frac{m_1}{C_1 + C_f}} \; ; \qquad (11)$$

$$D_2 = -\frac{B_2}{C_2 + C_f}; \; E_2 = \frac{A_2 V_0}{C_2 + C_f} \sqrt{\frac{m_2}{C_2 + C_f}};$$

Substituting the value of arbitrary constants $D_1 E_1$ and $D_2 E_2$ into the general solution (10), we obtain:

$$X_1 = \frac{C_1 X_{01}}{C_1 + C_f} \cos\omega_{01} t - \frac{A_1 V_0}{C_1 + C_f} \sqrt{\frac{m_1}{C_1 + C_f}} \sin\omega_{01} t + \frac{A_1 V_0}{C_1 + C_f} t - \frac{C_1 X_{01}}{C_1 + C_f}; \qquad (12)$$

$$X_2 = \frac{C_2 X_{02}}{C_2 + C_f} \cos\omega_{02} t - \frac{A_2 V_0}{C_2 + C_f} \sqrt{\frac{m_2}{C_2 + C_f}} \sin\omega_{02} t + \frac{A_2 V_0}{C_2 + C_f} t - \frac{C_2 X_{02}}{C_2 + C_f};$$

Wetransform Equation (12) asfollows:

$$X_1 = -G_1 \sin\left(\sqrt{\frac{C_1 + C_f}{m_1}} t + \beta_1\right) + \frac{A_1 V_0}{C_1 + C_f}; \qquad (13)$$

$$X_2 = -G_2 \sin\left(\sqrt{\frac{C_2 + C_f}{m_2}} t + \beta_2\right) + \frac{A_2 V_0}{C_2 + C_f};$$

Where, $G_1 = \sqrt{D_1^2 + E_1^2}; \beta_1 = arctg\frac{D_1}{E_1};$

Respectively, forthesecondsystem:

$$G_2 = \sqrt{D_2^2 + E_2^2}; \; \beta_2 = arctg\frac{D_2}{E_2};$$

Where,G_1 and G_2 are the amplitudes of natural vibrations of the working drum system;β_1 andβ_2 are the phase shift angles of the natural oscillations of the system. Equation (12) is the mathematical description of the load of the "working drum-stationary knife" system with cotton fiber from the moment of their interaction, taking into account the dynamics of the system, and allows to analyze the influence of the surface rigidity of the "working drum-stationary knife" system on the tightening process. Exploring equation (12), consider the case when $m_1 = 0.251 \, kg, m_2 = 0.751 \, kg, q = 100 \, N/cm^2 \, \delta_0 = 0.35mm, C_1 = 400 \, N/cm^2, t = 0.0152 \, sec.$

1. $C_1 = 600 \, N/mmcm^2$,a working drum made of RKM-2 is pressed in with a force of *N=5tf*;
2. $C_2 = 400 \, N/mmcm^2$,knife thickness h=2.5 mm;
3. $C_1 = 1100 \, N/mmcm^2$;*N=10tf*;
4. $C_2 = 4500 \, N/mmcm^2$;knifethickness*h=8mm;*

Results And Discussion:-

The results of numerical calculations for equation (12) after processing on a computer are presented in the form of graphs in Figs.3 and Fig.4. It can be seen from the graphs that the process of interaction of the working drum and the knife at the moment of tightening the fiber bundle is of an oscillatory nature. It should be noted that the periodic action of the working drum-stationary knife system on the tightened bundle of fibers contributes to the entrainment of the tightening force, which is important when the rotary knife organ is applied to the ginning fly.
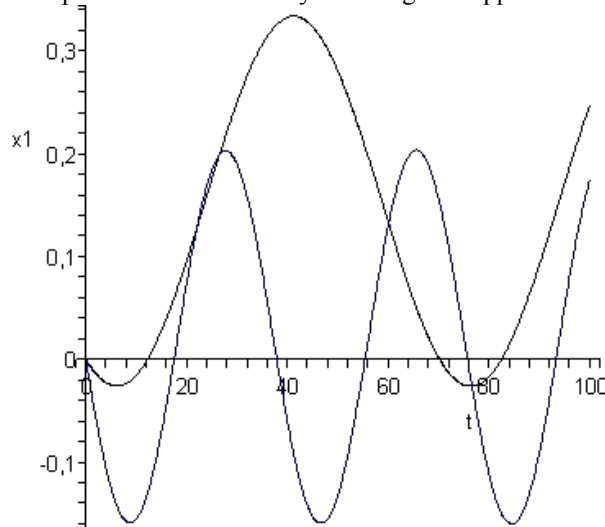

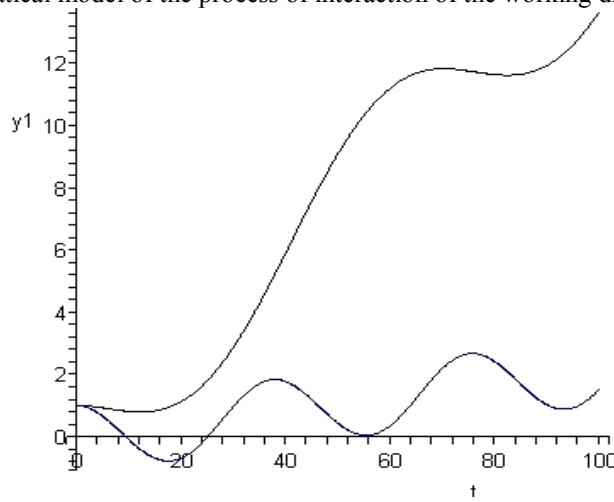**Fig.3:-** Mathematical model of the process of interaction of the working drum with cotton fiber.

Fig.4:- Mathematical model of the process of interaction of a knife with cotton fiber.

An important point of the analysis is the assessment of the loading of the fiber (the removed bundle of fibers) in the process of pulling it by the knife and the effect of the system parameters on it. The deformation of the fiber bundle from the pressure of the surface of the working drum and knife can be found from the following expressions:

$$(X_{f1} - X_1) = \Delta f_d; \tag{14}$$
$$(X_{f2} - X_2) = \Delta f_k;$$

Knowing the deformation of the fiber bundle due to vibrations under the system, it is not difficult to determine the additional pressure on the fiber.

$$P_d = \Delta f_d C_f; \tag{15}$$
$$P_k = \Delta f_k C_f;$$

Thetotalpressureincrementwillbe:

$$P = P_d + P_k; \tag{16}$$

The total pressure on the fiber bundle, taking into account the pressure of the preliminary pressing of the knife, is determined:

$$P_t = \sum P + P_0;$$

Where, $P_0 = C_1 X_0;$- preliminary pressure of the knife pressing.Fig.5 and Fig.6 shows in the form of graphs the nature of the change in the additional pressure on the pulled fiber bundle from the vibrations of the elastic surface of the "working drum + stationary knife" system during ginning.The nature of the change in the additional pressure on the pulled fiber bundle from the oscillation of the elastic surface of the "working drum-knife" system.
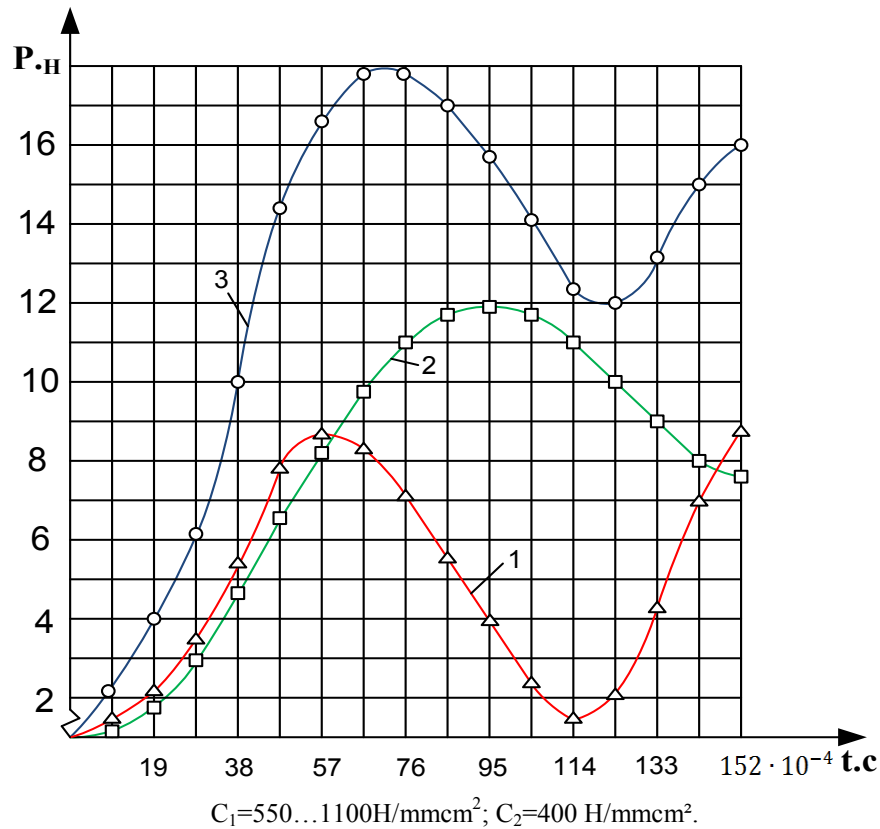

$C_1 = 550\ldots1100 H/mmcm^2; C_2 = 400\ H/mmcm^2.$

Fig.5:- The nature of the change in the additional pressure on the pulled fiber bundle.

Where, respectively, for the first and second cases: curve 1 is the pressure change from oscillations of the surface of the working drum; curve 2 is the change in pressure from vibrations of the knife surface, curve 3 is the total non-change in the pressure of the "working drum–stationary knife" system on the tightened bundle of fibres.

Analyzing curves 3 (Fig. 5) and (Fig. 6), we come to the conclusion that the change in pressure in the process of pulling the fiber bundle of the fly by the knife depends significantly on the ratio of the surface rigidity of the "working drum – knife" system.
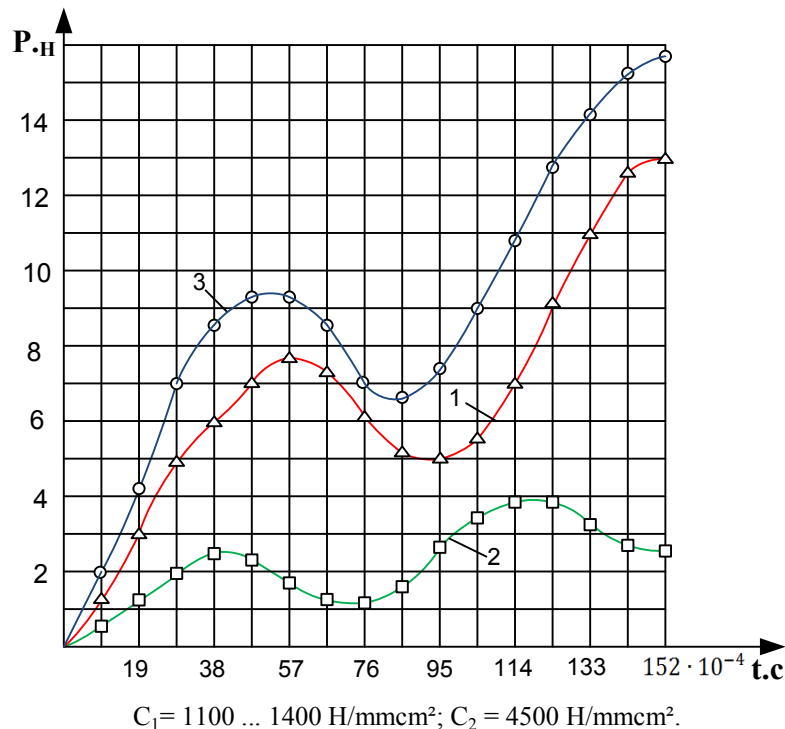
$C_1= 1100 \ldots 1400$ H/mmcm²; $C_2 = 4500$ H/mmcm².

Fig. 6:- The nature of the change in the additional pressure on the pulled fiber bundle.

Thus, it can be seen that the second case, curve 3 (Fig. 6), is more preferable, where the pressure on the fiber bundle changes periodically, due to vibrations of the elastic surface of the working drum. This will increase the gripping and tightening capacity of the working drum material, which leads to intensification of the process of fiber separation from the seed.

Conclusion:-
Thus, mathematical models of fiber loading in the process of its pulling by the working drum over the knife have been obtained, which allow analyzing and choosing the main parameters of the rigidity of the working drum-stationary knife system of the roller gin.

References:-
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