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Dynamics of Working Parts of the Cotton Cleaner From Small Trash 1XKM-12

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Abstract:

The article presents a kinematic scheme and the principle of operation of a fibrous material cleaner from small trash with twelve sequentially installed stake cylinders. On the bases of decision problems of dynamics of machine unit cleaner taking into account the mechanical features of the motors, the elastic-dissipative properties of the elastic transmission delay and processing loads of cleaned cotton the regularities of change of angular velocity, their non-uniformity and loading drive built graphical dependence of parameters, proved the best parameter values of the cleaner fibrous material. The positive effect of cleaning the fiber material based on the results of comparative production tests of the recommended machine is presented.

Keywords **—Fibrous material, cleaner, small trash, cotton, cylinder, mesh, effect.**

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I. INTRODUCTION

With existing constructions of raw cotton cleaners from small trash, the cleaning effect is achieved by increasing the cleaning zone, that is, by the number of consistently installed sawing cylinders and mesh surfaces under them [1,2]. In cleaners, raw cotton is fed to the cylinder at the end of the row, which rotates the raw cotton around itself from top to bottom on the perforated grids located below them and under the next cylinders in the row, after which the cylinders transport the raw cotton along these grids and the last cylinder unloads it from the cleaner [3,4]. The main drawback of this method is that its use does not ensure the achievement of a potentially high cleaning effect of the cleaner, which mainly depends on the number of impacts of cylinders on raw cotton. The more impact, the more loosened raw cotton and the more small impuritiesthrough the holes of the perforated grids.

With an increase in the number of saws on top of the cylinders are released, the damage to cotton fibers and seeds increases in parallel. It is important to improve the method and construction of raw cotton cleaners from small trash, allowing an increase in the cleaning effect, reducing the power required while minimizing damage to cotton fibers and seeds.

II. MATERIALS AND METHODS

A. *Effective construction of the cotton cleaner from small trash*

Twelve ripping cylinders with perforated grids located under them, feeding rollers, three baskets and a shaft (see Fig. 1). This cleaner differs from the serial cleaner only by the location of the feed rollers above the ripping cylinders, which are installed three cylinders away from the end cylinder. The cleaner works as follows.

Feeding rollers to the ripping cylinders feed raw cotton, which is transported above them in the direction of the rightmost cylinder, which moves the raw cotton from top to bottom on the perforated gratings. Then all the other cylinders transport the raw cotton through perforated grids in the direction of the left-most cylinder and then to the shaft through which the raw cotton is discharged from the cleaner. When transporting raw cotton by loosening cylinders, weeds are separated from it, mainly small ones, which are released by air flows through holes in the perforated gratings into the hopper and through holes in their lower part are released from the cleaner [7,8]. The recommended construction of the 1XKM-12 cleaner contains a feeder and 12 grate cylinders with heat-removing grids under them. The rotational movement of the feed rollers and stake cylinders is obtained from six identical asynchronous motors of the 4A112M643 brand, with P=3.0 kW, $n=945$ *rpm* and belt gears. The gear ratio for grate cylinders $U_m=2.25$. Then, $n_c=420$ *rpm*, $\omega_c=43.96\ s^{-1}$.

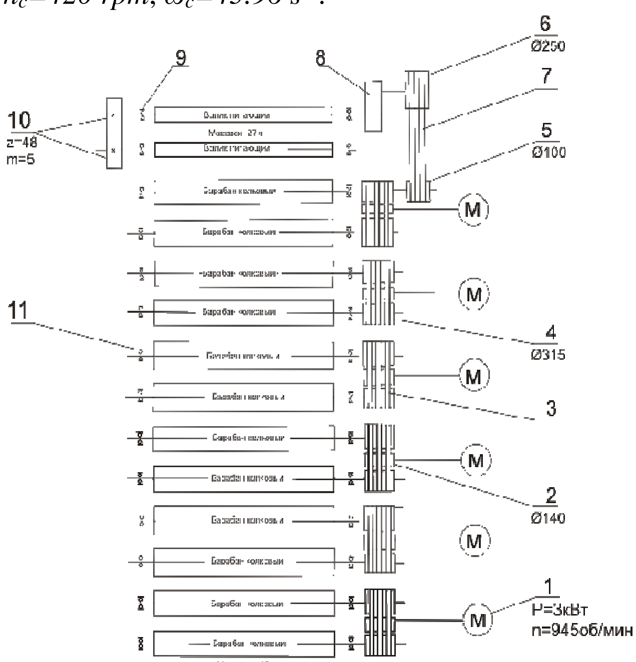


Fig.1. Kinematic diagram of the 1XKM-12 cleaner.

The feed rollers rotate at a frequency of (0÷20) rpm or ω_p=3.1 s^{-1}. It should be noted that in the raw cotton cleaner from small trash 1XKM-12, the first four stake cylinders experience the greatest loads due to the transportation and dragging of cotton on the mesh surfaces, and the remaining pegboard cylinders only drag the cotton on the mesh surfaces. In addition, given the power required to rotate the regulator and feed rollers, the load on the first two stake cylinders will be even greater than on the other two adjacent cleaner cylinders.

During operation, the 1XKM-12 cleaner allows the necessary loosening and cleaning of raw cotton from small trash. The task of the research included finding the law of variation of non-uniformity stake cylinders, feed rollers and rotor of the induction motor and changes in torque on the shafts taking into account moments of inertia of the working parts elastic-dissipative characteristics of belt drives and load from cleaned raw cotton in various performance machine.

III. RESULTS AND DISCUSSION

B. Mathematical modeling of the movement of a machine unit driven by a feeder and staking cylinders

The constructional scheme of the machine unit in fig.2 is shown.

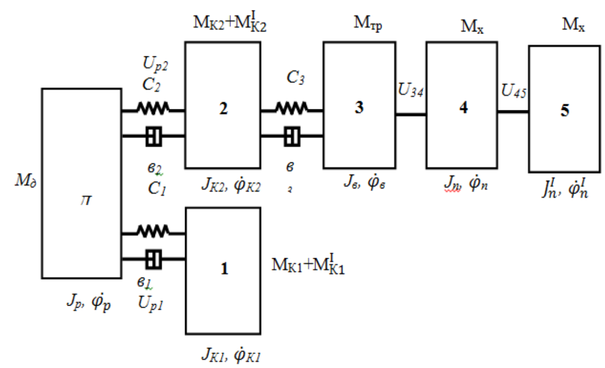


Fig.2. Calculation diagrams of a machine unit with a feeder drive and a grating cylinder cleaner 1XKM-12

According to the construction scheme of the machine unit (fig.2) using the Lagrange II-rode equations (1) we will make a system of differential equations of the machine unit with the drive mechanism of the feed rollers and the first two stake cylinders of the 1XKM-12 cleaner:

$$\dot{M}_\partial = 2M_K\omega_c - 2M_\kappa \cdot \rho \cdot \dot{\varphi}_p - \omega_c S_K M_\partial,$$

$$J_p \cdot \ddot{\varphi}_p = M_{\partial} - c_1 \cdot (\varphi_p - u_{p1} \cdot \varphi_{K1}) - c_2 \cdot (\varphi_p - u_{p2} \cdot \varphi_{K2}) - \text{в}_1 \cdot (\dot{\varphi}_p - u_{p1} \cdot \dot{\varphi}_{K1}) - \text{в}_2 \cdot (\dot{\varphi}_p - u_{p2} \cdot \dot{\varphi}_{K2});$$

$$J_{K1} \cdot \ddot{\varphi}_{K1} = c_1 U_{p1} \cdot (\varphi_p - u_{p1} \cdot \varphi_{K1}) + \text{в}_1 U_{p1} \cdot (\dot{\varphi}_p - u_{p1} \cdot \dot{\varphi}_{K1}) - M_{K1} - M_{K1}^I;$$

$$J_{K2} \cdot \ddot{\varphi}_{K2} = c_2 U_{p2} \cdot (\varphi_p - u_{p2} \cdot \varphi_{K2}) - c_3 \cdot (\varphi_{K2} - u_{23} \cdot \varphi_{\text{в}}) + \text{в}_2 U_{p2} \cdot (\dot{\varphi}_p - u_{p2} \cdot \dot{\varphi}_{K2}) - \text{в}_3 \cdot (\dot{\varphi}_{K2} - u_{23} \cdot \dot{\varphi}_{\text{в}}) - M_{K2} - M_{K2}^I;$$

$$J_{\text{в}} \cdot \ddot{\varphi}_{\text{в}} = c_3 U_{23} \cdot (\varphi_{K2} - u_{23} \cdot \varphi_{\text{в}}) + \text{в}_3 U_{23} \cdot (\dot{\varphi}_{K2} - u_{23} \cdot \dot{\varphi}_{\text{в}}) - M_{TP} - M_{34};$$

$$J_n \cdot \ddot{\varphi}_n = U_{23} \cdot M_{34} - M_x - M_{45};$$

$$J_n^I \cdot \ddot{\varphi}_n^I = U_{45} \cdot M_{45} - M_x. \quad (1)$$

where, $\dot{\varphi}_p, \dot{\varphi}_{C1}, \dot{\varphi}_{C2}, \dot{\varphi}_{\text{в}}, \dot{\varphi}_{n1}, \dot{\varphi}_{n2}$ – the angular velocities of the rotor of the asynchronous motor, the first and second ring cylinders, the output shaft of the variator and the feed rollers; M_m, M_C – the moment on the motor rotor and its critical value; ω_c, P – the angular frequency of the network and the number of pairs of poles; S_C – the critical sliding motion of the motor rotor; $U_{P1}, U_{P2}, U_{23}, U_{45}$ – the transfer ratio between the masses, $M_{C1}, M_{C1}^I, M_{C2}, M_{C2}^I, M_{34}, M_{45}, M_x$ – moments of technological resistance to the working parts and moments between the masses; $C_1, C_2, C_3, \text{в}_1, \text{в}_2, \text{в}_3$ - coefficients of circular stiffness and dissipation of elastic gears.

The numerical solution of the system (1) was made on a computer taking into account the following system parameters: motor *4A112MA6UZ3, P=3,0 kW, n=945 rpm,* f_c*=50 Hz,* $\cos\varphi = 0{,}86$*;* ω_0*=157.1* s^{-1}*; n=0.83;* ω_C*=98.91* s^{-1}*;* S_H*=0.052;* S_C*=0.193; P=2;* $U_{p1}=U_{p2}$*=2.25;* U_{23}*=2.5;* U_{34}*=8.4;* U_{45}*=1.0;* J_P*=0.117 kgm*^{2}*;* J_{C1}*=2.94 kgm*^{2}*;* J_{C2}*=3.71 kgm*^{2}*;* $J_{\text{в}}$*=0.398 kgm*^{2}*;* J_n*=0.189 kgm*^{2}*;* J_n^I *=0.171 kgm*^{2}*;* C_1*=(200÷250) Nm/rad;* C_2*=(220÷260) Nm/rad;* C_3*=(160÷180) Nm/rad;* в_1*=(4.0÷6.0) Nms/rad;* в_2*=(4.5÷6.5) Nm·s/rad;* в_3*=(3.5÷4.0) Nm·s/rad.*

C. Solving the problem of machine unit dynamics and analyzing the results.

The system of differential equations was solved under the following elemental conditions:

$$t = 0;\ \dot{\varphi}_p = 0;\ \dot{\varphi}_{C1} = 0;\ \dot{\varphi}_{C2} = 0;\ \dot{\varphi}_1 = 0;\ \dot{\varphi}_2 = 0;\ M_x = 0;\ M_C = 0.$$

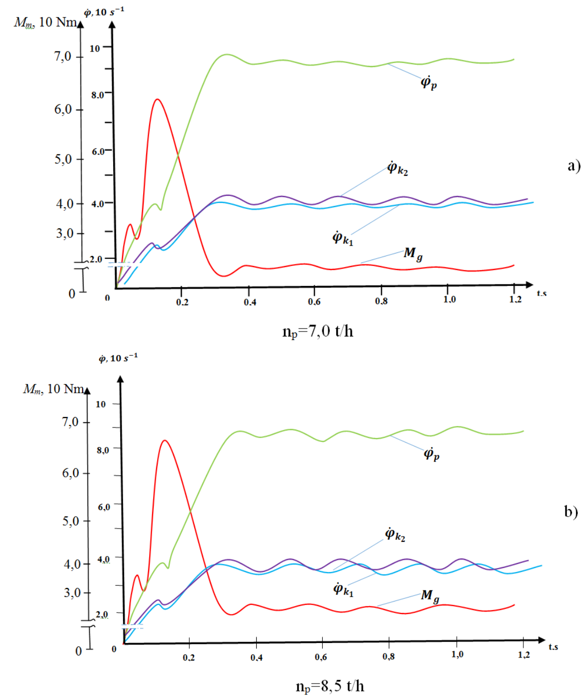
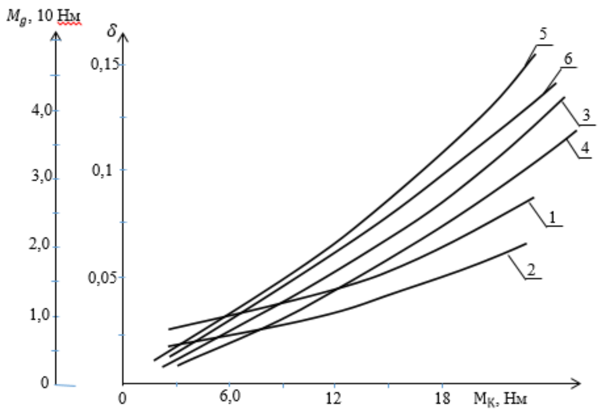


Fig.3. Regularities of movement of the engine rotor, staking cylinders and the moment Mm of the machine unit of the 1XKM-12 cleaner

Based on the results of numerical solution of the problem, the regularities of changes in the engine rotor, staking cylinders and engine load are obtained, which are shown in fig.3.

The analysis of the obtained laws of motion of the engine rotor and stake cylinders shows that the system reaches the steady state in 2.9 seconds with the technological load demand from cotton. At the same time, the frequency of vibrations of the driving moment of the electric motor, the angular speeds of the rotor and the stake cylinders, the cotton supply of the 1XKM-12 cleaner zone depends on the change in the technological load demand.

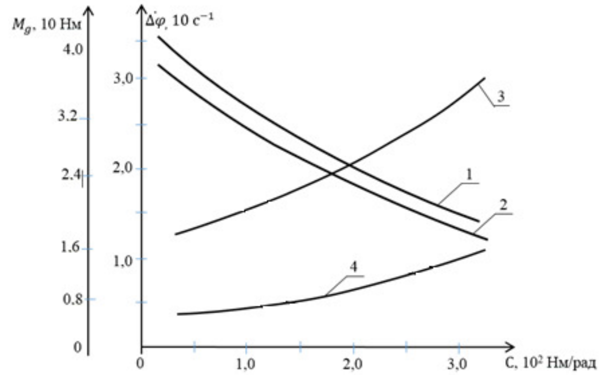
Analysis of the obtained dependencies of the angular velocities of the stake cylinders according to Figure 3 shows that with increasing productivity, the values of angular velocity fluctuations increase, but their average values decrease accordingly. On the basis of processing of the received laws of motion at changes of productivity, coefficients of rigidity of belt transfers graphic dependences are constructed on fig.4 graphic dependences of change of a torque on a shaft of the electric motor and coefficients of unevenness of angular speeds on shafts of the first two staking cylinders are presented.



Where, 1,2 -$M_m = f(M_k)$н ; 1,3,5-at $J_{k_1} = 3{,}2$ кгм^2; $J_{k_2} = 3{,}9$ кгм^2; 2,4,6- at $J_{k_1} = 2{,}8$кгм^2; $J_{k_2} = 3{,}4$кгм^2; 3,5-$\delta_{k_1} = f(M_k)$; 4,6-$\delta_{k_2} = f(M_k)$;

Fig.4. Graphical dependences of changes in the torque on the rotor shaft of the electric motor and the coefficient of unevenness of the angular velocity on the shafts of the first two pegboard cylinders on changes in the load from cotton

It should be noted that a certain unevenness of rotation of the peg cylinders contributes to the effective loosening of cotton and the release of weed impurities. An increase M_C from 2.6 km to 19.5 km at J_{C1}=2.8 kgm^2 and J_{C2}=3.4 kgm^2 leads to an increase in the non-uniformity of rotation of the first staking cylinder from 0.009 to 0.112, and at large values of the moments of inertia of the stake cylinders, the coefficients of non-uniformity of the angular velocities of the stake cylinders are located in the aisles $\delta_{c1}=0.012\div0.13$ and $\delta_{c2}=0.011\div0.101$. Based on the results of experimental studies [11,12], it is known that a significant cleaning effect in the saw cleaning sections is achieved at $\delta \geq (0.15\div0.25)$ [13,14]. Therefore, to ensure the necessary effect of cleaning cotton in a 1XKM-12 machine, the recommended parameter values are: $M_C \leq (14.0\div16.0)$ Nm; $J_{C1}=(2.2\div2.8)$ kgm^2; $J_{C2}=(3.0\div3.4)$ kgm^2, $J_1=J_2=(2.0\div2.2)$kgm^2; $J_5=J_6=...=J_{12}=(1.8\div2.0)$ kgm^2.



where, $1 - \Delta\dot{\varphi}_{k_1} = f(C_1)$; $2 - \Delta\dot{\varphi}_{k_2} = f(C_2)$; $3 - M_g = f(C_1, C_2)$;
$4 - M_{k_1} = M_{k_2} = f(C_1, C_2)$;
at $M_{k_1} + M_{\dot{k}_1} = 12 + 1{,}5\, sin\omega t$ (Нм), $M_{k_2} + M_{\dot{k}_2} = 14 + 1{,}7\, sin\omega t$(Нм).

Fig.5. Graphic dependences of the change in the excursion of angular speeds of staking cylinders and loading moments on the change in the coefficients of circular stiffness of belt drives

When increasing the belt drive stiffness, c_1 from $0.5\cdot10^2$ Nm/rad to $3.4\cdot10^2$ Nm/rad leads to a decrease $\Delta\dot{\varphi}_{K1}$ from 36 s^{-1} to 16.6 s^{-1} and, accordingly, decreases $\Delta\dot{\varphi}_{K2}$ from 34.1 s^{-1} to 14.7 s^{-1} (fig.5). It is Important to note that an increase in c_1 and c_2 leads to an increase M_m, according to a nonlinear pattern. Thus, the torque on the engine shaft increases from 15,7 Nm to 35,3 Nm, and the average torque on the shaft of the second ring cylinder increases from 4,1 Nm to 10,5 Nm. When transporting and hauling cotton, the range of vibrations of their angular velocities will be large due to the corresponding resistances from the cotton. In the beginning, the cotton will be less loosened and then the cotton will be more loosened. Therefore, the rigidity of belt drives should be reduced as the cotton is dragged. Therefore, the recommended values are: $c_1=(220\div250)$ Nm/rad; $c_2=(270\div330)$ Nm/rad; $c_3=(180\div200)$ Nm/rad.

In the drive of the first three pairs of prick cylinders, three belts should be installed (in parallel), and in the next three pairs of prick cylinders, two belts should be installed. Accordingly, the power of the first three electric motors is recommended to choose 3,0 kW, and the next three electric motors with a power of 2,2 kW, which provide the required modes of movement of the peg cylinders and the necessary effect of cleaning cotton from small trash. At the same time, the life of the machine increases by up to 20 %, and the power consumption is reduced to (5,0-5,5) kW.

Based on the recommended parameters of the elements of the 1XKM-12 cleaner machine unit, an experienced machine abrasive was manufactured and tested. The test results show that the efficiency of cotton cleaning increases on average by (10÷11) % relative to the production machine. In this case, the cleaning effect of small trash increases to (8.0÷10) % relative to the existing small trash cleaner.

It should be noted that the increase in damage will be less in the recommended machine by (0.1÷0,15) % relative to the serial version. Moreover, with the effect of cleaners for low grades of cotton will also be important by (9.0÷10) % relative to the production machine.

IV. CONCLUSIONS

An effective construction scheme for cotton cleaner from small trash has been developed. Based on the decision of problems of dynamics of machine unit cleaner taking into account the mechanical characteristics of the engine, elastic-dissipative properties of the elastic transmission delay and processing loads of purified cotton the regularities of change of angular velocity, their non-uniformity and loading drive built graphical dependence of parameters, proved the best parameter values of the cleaner of fibrous material carried out production tests.

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