Designing and Methods of Calculating Parameters of a Fibrous Material Cleaner From Large Litter

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Abstract

The constructive scheme and the principle operation of the fiber material cleaner from large litter are presented in this article. The results of theoretical studies of dynamics of machine aggregate with gear mechanisms, rotary drums and screw area received laws engine working parts. Recommended values of parameters and modes of their movement are defined. Experiments are substantiated by comparative industrial experiments of the highest effect of cleaning the fibrous material in the recommended cleaner.

Keywords: *a cleaner, fibrous material, large litter, dynamics, angular velocity, span, oscillation, moment, stiffness, dissipation, process load, effect.*

Introduction.

The technological line for cleaning fibrous material includes a zone of large and small cleaning [1]. The main drawback of fibrous material cleaner from large litter is the low cleaning effect and frequent slaughtering of the material in the cleaning zones [2,3]. In the present the construction of raw cotton cleaner, for various reasons, it happens slaughtering with raw cotton between holding saw-cylinder and flat casing, in which raw cotton is so highly compacted that the resistance to the rotation of the saw cylinder exceeds the capacity of the gear and first slowing, then stopping rotation of the saw cylinders. In so doing, the loosening drum and the free space around it are also filled with raw cotton, including the ridged surface of the saw cylinder is filled with raw cotton. Since the drive of all the gripping saw cylinders and the loosening drum is carried out from a single electric motor, the rotation is slowed down at the same time as the clogged saw cylinder, and then the loosening drum and all the saw cylinders are stopped.

To eliminate slaughters, it is necessary to clean capturing saw cylinders and grate from raw cotton , which is done manually is labor intensive and time-consuming operation. Since the slaughters in the gaps between the saw-cylinder and grate the raw cotton is compacted so that practically defies plucking with fingers or pulling to the special hooks.

Therefore, the cleaning of the saw cylinders and the capturing from raw cotton is carried out as follows. While removing slatted drums rotating in the operating mode, the pulley wheels of the drive of the gripping saw cylinders are manually scrolled by special levers in the direction opposite to the working regime of their rotation.

Pinching off between saw teeth and grate of raw cotton does not have much resistance to movement of the back sides of the teeth of saws are carried out due to frictional forces. The slaughter of separate briefing and slices of raw cotton, which either falls through the gaps between the grates or removable slatted drums from the back sides of the teeth of the saw cylinder and unloaded from the cleaner.

To accelerate the process of removing raw cotton from slaughter, the direction of manual scrolling of the saw cylinders drastically changed, in order to re-cut of saw teeth into the slaughter, then the direction of rotating the saw cylinders and change the back side of the teeth carried out of slaughter to the next portion of raw cotton.

Frequently repetition of this operation ensures that the gaps between the saw cylinders and grates are assured of raw cotton, after which the electric motor for driving the rotation of the saw cylinders and the ripping drum is turned on. Thus, if raw cotton filled at the time of slaughter ripping

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drum and the space around it had compacted, the upper saw cylinder, the saws of which is a layer of raw cotton, moves it to the grate, gaining working speed and producing the accumulated raw cotton. If the accumulated raw cotton stops to the rotation of the feeding rollers compacted sufficiently, that is the slaughter of upper saw cylinder's bottom and repeats its above-described cleaning process. At cotton gins, the process of cleaning the raw cotton cleaner from the slaughter lasts from 10 to 20 minutes [4,5,6,7]. Relative to this, it is considered appropriate to improve the design of the cleaner, as well as the justification of parameters based on deep dynamic studies.

Development of the design of a cleaner of fibrous material from large litter.

The proposed structural scheme for the purification of fibrous material from large litter is shown in Fig. 1.

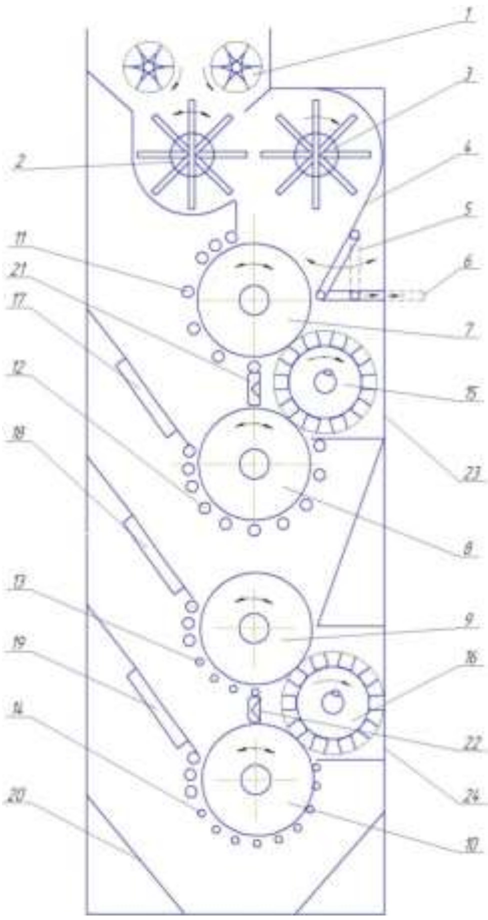


Fig .1. Diagram of the cleaner of fibrous material from a large litter

The cleaner contains two feed rollers 1, loosening drums 2 and 3, a tray 4, a rotary guide 5, a reflective plate 6, gripping saw cylinders 7, 8, 9 and 10, grates 11, 12, 13 and 14, removing planed drums 15 and 16, inclined trays 17, 18, 19 and 20, guides 21 and 22, exiting meshes 23 and 24.

The operation of the cleaner in the working mode of cleaning raw cotton is carried out as follows. Raw cotton is fed by feeding rollers 1 to the first Ripper 2 located below them, which is driven by the first saw cylinder 7, which rotates in the direction of sharpening the teeth of its saws (in the figure – counterclockwise).

The first ripping drum 2 directs the raw cotton to the second ripping drum 3, which rotates in the opposite direction from the first ripping drum 2 (clockwise in the figure) and feeds the raw cotton through the tray 4 and the rotating guide 5 installed behind the face with it to the first upper gripping saw cylinder 7, which cleans the raw cotton on the grates 11, after which the removing of stripping drum 15 on the reflective plate 6 directs the cleaned raw cotton to the spout opening 23.

Allocated through the gaps between the grate bars 11 of weeds and fallen with them, the briefing of raw cotton in the tray 17 are sent to a second exciting of the saw cylinder 8, which clears the briefing on the grate 12, and then removing the slatted drum 15, and then removing to header 21, to the rear side of the teeth of saws of the cylinder 8 and the reflective plate 6 directs cleaned leaflet of bleach raw cotton into spout opening 23.

The processes of regeneration and cleaning of raw cotton flyers on saw cylinders 9 and 10 are similar to those described above, and the cleaned flyers are removed from these saw cylinders by a removing slat drum 16, which directs them to the second discharge spout opening 24 [8,9].

It should be noted that the construction can only include three saw-grate zones for cleaning fibrous materials and the fourth saw cylinder 10 is replaced by a heat-removing screw, and the removing planed drum 16 engages only the saw cylinder 9. In order to proof the parameters of the machine theoretical dynamic studies are given

Dynamics of the machine unit with mechanisms for driving saw and bar drums of the PT-10 cotton cleaner.

The kinematic scheme of the PT-10 cleaner includes three asynchronous motors of the following brands: 4AM132M6U1, P=7,5 kW, n=950 rpm; 4AM132S6U2, P=5,5 kW, n=960 rpm; DELIXIEM60GIRSTB4, P=1,5 kW, n=1000 rpm, RV-0,75 gearbox; I=1/100. A feature of the drive mechanisms of the PT-10 cleaner is the transfer of movement to the second bar drum with a gear ratio less than one.

The machine unit with a mechanism for driving the feed rollers is presented as a linear three-mass system with a rigid transfer ratio between the masses. The second machine unit with the drive gears of the slat and first bar drums in the form of a four-mass linear system with elastic gears. The third machine unit with mechanisms for driving saw blades and the second bar drum and a combined auger in the form of a six-mass system with two branches.

Taking into account that the main working part of the cleaner is only saw drums and grates. Let's consider only the dynamics of the third machine unit (see Fig.2).

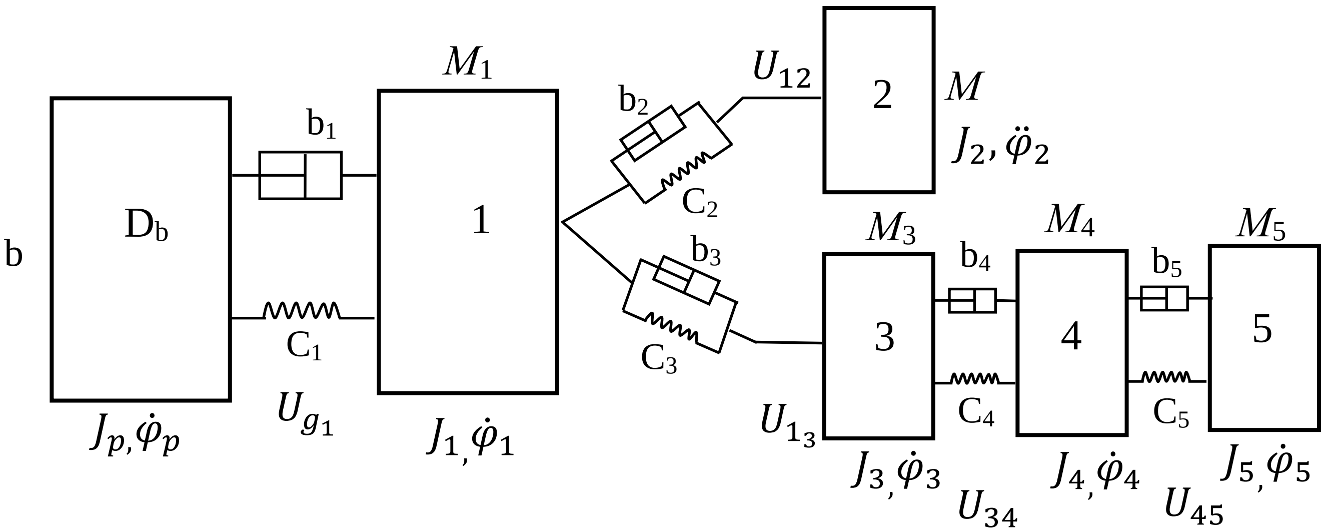


Fig.2. Dynamic model of the machine unit for rod gear mechanisms, slatted drums, cotton cleaner PT-10

A system of differential equations describing the dynamics of a machine unit with mechanisms for driving saw drums and a second bar drum cleaner:

$$\frac{\omega_0 - \dot{\varphi}_n}{\omega_0} = \frac{S_K}{2M_K} M_\partial + \frac{1}{2\omega_c M_K} = \dot{M}_\partial;$$

$$J_p \cdot \ddot{\varphi}_p = M_\partial - c_1 \cdot (\varphi_p - u_{\partial 1} \cdot \varphi_1) - в_1 \cdot (\dot{\varphi}_p - u_{\partial 1} \cdot \dot{\varphi}_1) \qquad (1)$$

$$J_1 \cdot \ddot{\varphi}_1 = U_{\partial 1} \cdot C_1(\varphi_p - u_{\partial 1} \cdot \varphi_1) + U_{\partial 1} \cdot в_1 \cdot (\dot{\varphi}_p - u_{\partial 1} \cdot \dot{\varphi}_1) - C_2(\varphi_1 - u_{12} \cdot \varphi_2) - C_3(\varphi_1 - u_{13} \cdot \varphi_3) -$$
$$- в_2 \cdot (\dot{\varphi}_1 - u_{12} \cdot \dot{\varphi}_2) - в_3 \cdot (\dot{\varphi}_1 - u_{13} \cdot \dot{\varphi}_3) - M_1;$$

$$J_2 \cdot \ddot{\varphi}_2 = U_{12} \cdot C_2(\varphi_1 - u_{12} \cdot \varphi_2) + U_{12} \cdot в_2 \cdot (\dot{\varphi}_1 - u_{12} \cdot \dot{\varphi}_2) - M_2;$$
$$J_3 \cdot \ddot{\varphi}_3 = U_{13} \cdot C_3(\varphi_2 - u_{13} \cdot \varphi_3) + U_{13} \cdot в_3 \cdot (\dot{\varphi}_1 - u_{13} \cdot \dot{\varphi}_3) - C_4(\varphi_3 - u_{34} \cdot \varphi_4) - в_4 \cdot (\dot{\varphi}_3 - u_{34} \cdot \dot{\varphi}_4) - M_3;$$
$$J_4 \cdot \ddot{\varphi}_{\$4} = U_{34} \cdot C_4(\varphi_3 - u_{34} \cdot \varphi_4) + U_{34} \cdot в_4 \cdot (\dot{\varphi}_3 - u_{34} \cdot \dot{\varphi}_4) - C_5(\varphi_4 - u_{45} \cdot \varphi_5) - в_5 \cdot (\dot{\varphi}_4 - u_{45} \cdot \dot{\varphi}_5) - M_4;$$
$$J_5 \cdot \ddot{\varphi}_5 = U_{45} \cdot C_5(\varphi_4 - u_{45} \cdot \varphi_5) + U_{45} \cdot в_5 \cdot (\dot{\varphi}_4 - u_{45} \cdot \dot{\varphi}_5) - M_5;$$

Where, $M_4 = M_{14M} \pm \delta(M_{4M});\ M_5 = M_{5M} \pm \delta(M_{5M})$.

$\varphi_p, \varphi_1, \varphi_3, \varphi_4, \varphi_5, \varphi_2$ - respectively, the angular displacement of the rotor of the electric motor, saw drums, the second bar drums and weed screw; C_1, C_2, C_3, C_4, C_5 - coefficients of torsional stiffness of belt drives ; $в_1, в_2, в_3, в_4, в_5$ - coefficients of dissipation of the cleaner belts ; M_1, M_2, M_3, M_4, M_5 - technological resistance from cotton to the working parts of the cleaner; $U_{\partial 1}, U_{12}, U_{13}, U_{34}, U_{45}$ - transfer ratios of belt drives between the masses.

The main kinematic characteristics of the working parts of the PT-10 large-scale cotton cleaner are the angular speeds, the load of the shafts, and the transfer ratios of belt gears between the masses of machine units. In this case, the calculated values of the transfer ratios: for a machine unit with a saw and bar drum gear:

$U_{\partial n_1} = 0{,}5;$ $U_{12} = 3{,}28;$ $U_{13} = 1{,}0;$ $U_{24} = 1{,}0;$ $U_{45} = 0{,}83;$ $\dot{\varphi}_p = 100{,}5$ c^{-1}; $\dot{\varphi}_1 = 50{,}2$ c^{-1}; $\dot{\varphi}_2 = 15{,}3$ c^{-1}; $\dot{\varphi}_3 = 50{,}2$ c^{-1}; $\dot{\varphi}_4 = 50{,}2$ c^{-1}; $\dot{\varphi}_5 = 60{,}5$ c^{-1}.

The solution of the system of differential equations (1) describing the dynamics of the movement of the saw and bar drums, the heat- removing screw was carried out on a PC using special programs with the following initial knowledge of the parameters:

P=7.5 kW, n=960 rpm, $f = 50 Гц,$ $\cos\varphi = 0{,}87;$ $\omega_0 = 157{,}1$ s^{-1}; $\delta = 0{,}84;$ $\omega_H = 98{,}91$ s^{-1}; $S_H = 0{,}054;$ $S_K = 0{,}191;$ P=2; $U_{\partial 1} = 0{,}5;$ $U_{12} = 3{,}28;$ $U_{13} = 1{,}0;$ $U_{34} = 1{,}0;$ $U_{45} = 0{,}83;$ $J_p = 0{,}121 kgm^2;$ $J_1 = 3{,}52 kgm^2;$ $J_2 = 1{,}41 kgm^2;$ $J_3 = 3{,}18 kgm^2;$ $J_4 = 3{,}12 kgm^2;$ $J_5 = 2{,}5 kgm^2;$ $C_1 = 250 Nm/rad;$ $C_2 = 135 Nm/rad;$ $C_3 = 250 Nm/rad;$ $C_4 = 250 Nm/rad;$ $C_5 = 200 Nm/rad;$ $в_1 = 6{,}5 Nm \cdot s/rad;$ $в_2 = 3{,}9 Nm \cdot s/rad;$ $в_3 = 6{,}5 Nm \cdot s/rad;$ $в_4 = 6{,}5 Nm \cdot s/rad;$ $в_5 = 4{,}2 Nm \cdot s/rad;$ n_p=2,2 t/h.

According to the results of solving problem (1), the regularities of changes in the angular velocities of the motor rotor, saw and bar drums, as well as the heat-removing screw, the driving moment on the motor shaft are obtained, which are shown in Fig.3. According to the obtained regularities in Fig.3 it can be seen that the system enters the steady state for (0,22÷0,25) seconds, which also depends on the performance of the cotton cleaner. With an increase in productivity up to 3,0 t/h, the average values of angular velocities are reduced (table 1) for working

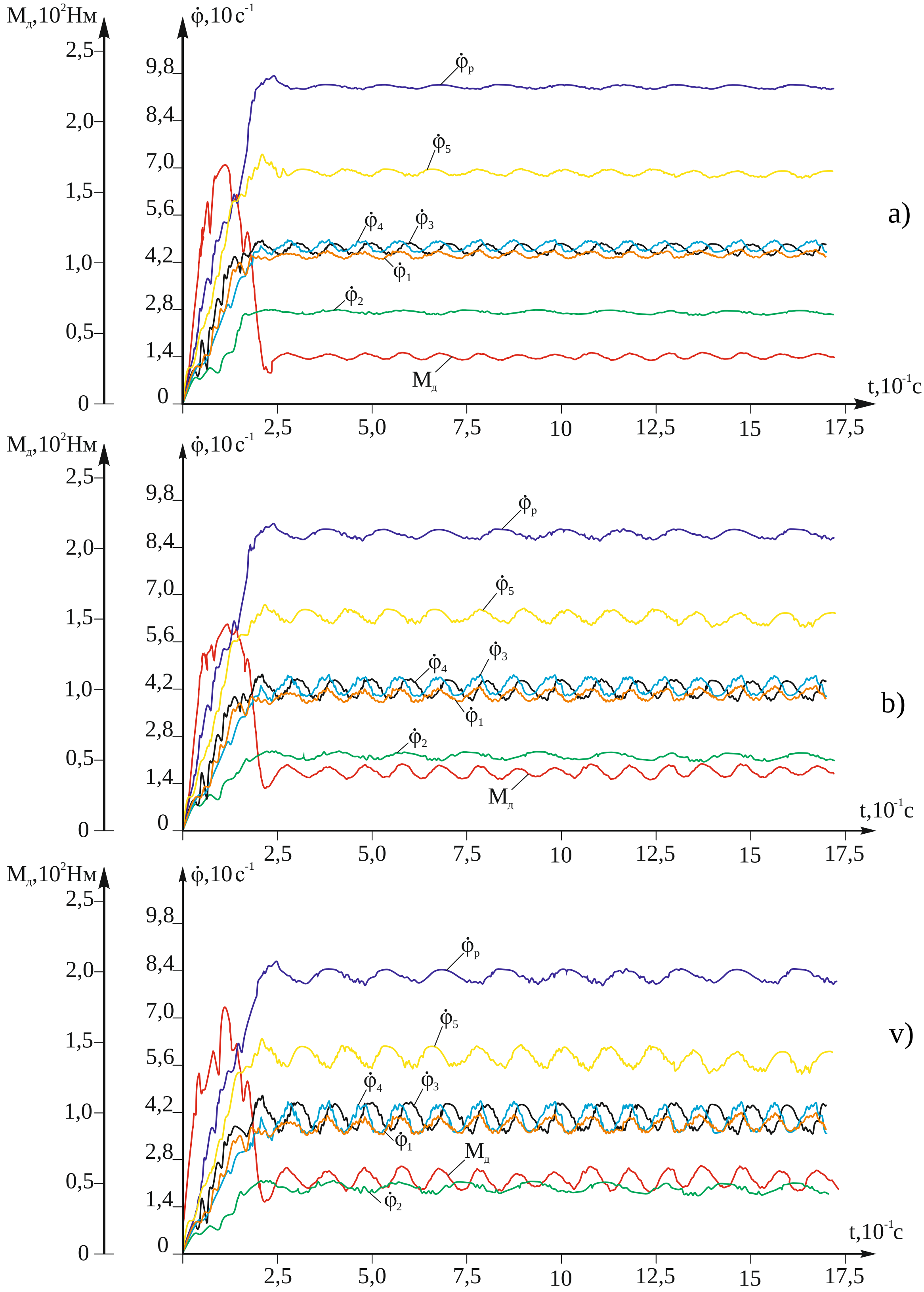


Fig.3. Regularities of changes in the angular velocities of the motor rotor, sawing and bar drums, as well as the heat- removing screw, the driving moment on the motor shaft.

$a - \text{at } n_p = 1{,}7 \text{ t/h}; b - \text{at } n_p = 2{,}2 \text{ t/h}; \ v - \text{at } n_p = 3{,}0 \text{ t/h}.$

bodies. But, at the same time, the angular velocity fluctuations increase, as well as the torque of the M_∂ increases.

The main elements of the cotton cleaner from large litter PT-10 are the cleaning zones, which involve three saw drums, grates under them. In the machine unit of this system, drives and a bar drum are also included, as well as a heat-removing screw (see Fig.1).

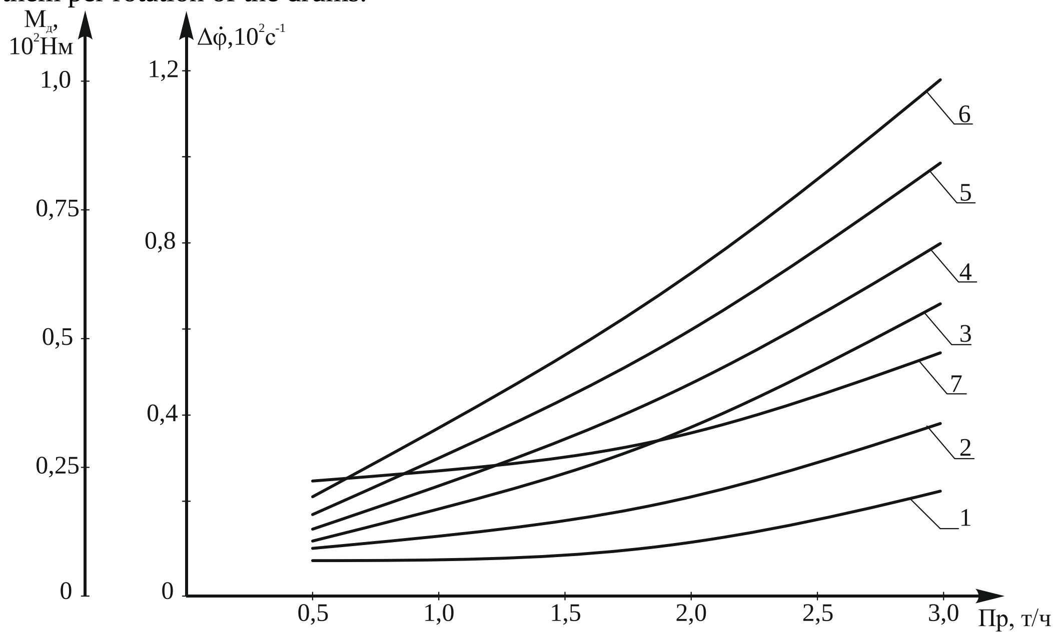
Table 1

Average values of angular velocities

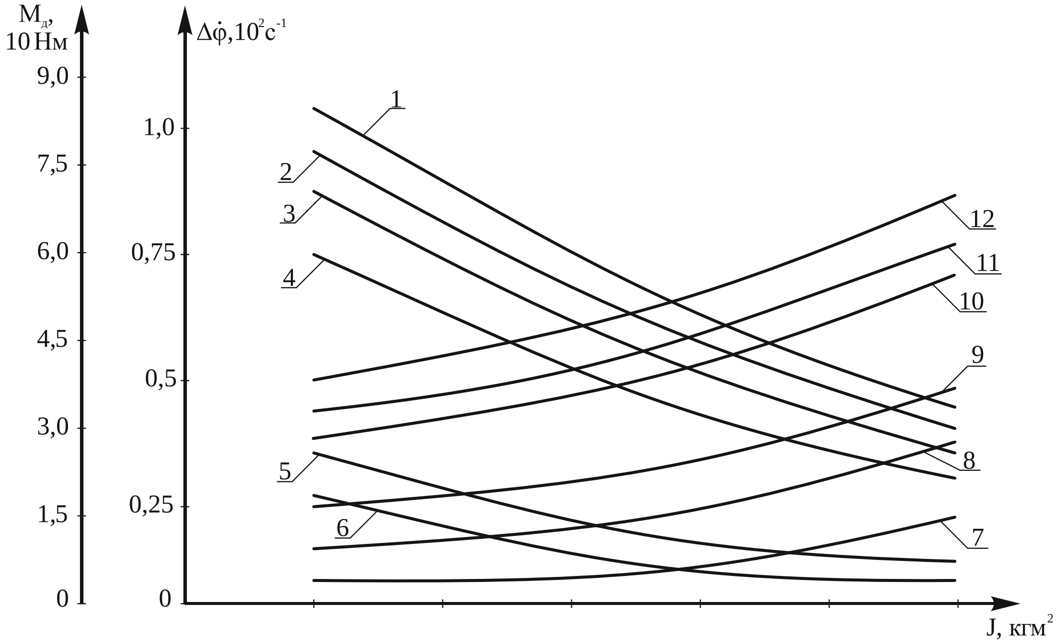
№	The name of the work on	The Angular velocity		
		n_p=1,7 t/h	n_p=2,2 t/h	n_p=3,0 t/h
1	Electric motor on the shaft	93,5	90,2	88,5
2	1st saw drum	46,6	42,1	40,2
3	2nd saw drum	45,9	41,8	39,7
4	3rd saw drum	45,4	41,3	39,2
5	Rod and reel	60,1	57,9	56,1
6	Heat- removing screw	18,7	15,2	14,7

Analysis of given table 1 shows that the average angular velocity of the gear speed decreases to (10÷12) %, the first saw drum to (5,1÷7,2) %, the second and third saw drums to (4,5÷5,1) %. The importance of research is that how to determine the engine load and the oscillation range of the saw and bar drums of the system with an increase in the performance of the PT-10 cleaner (Fig. 4). With an increase in performance from 0,5 t/h to 3,0 t/h, the torque on the engine shaft increases from 26,1 Nm to 41,3 Nm, and the angular velocity of the rotor increases from 5,1 s^{-1} to 11,3 s^{-1}.

Thus due to the sufficient values of the moment of inertia of the first saw drum, the oscillation angular velocity increases only up to 38 s^{-1}, and throws angular speed of second s and third saw drums increase to 76,2 s^{-1} and 82,3 s^{-1}. The throw of the angular velocity of the shaft of the heat-removing screw does not exceed (3,2÷3,3) s^{-1}. The frequency of changes in the angular velocities of the saw drums basically corresponds to the number of grates in the zone where cotton is dragged along them per rotation of the drums.



Where, $1 - \Delta\dot{\varphi}_p = f(\Pi p)$; $2 - \Delta\dot{\varphi}_1 = f(\Pi p)$; $3 - \Delta\dot{\varphi}_2 = f(\Pi p)$; $4 - \Delta\dot{\varphi}_{43} = f(\Pi p)$; $5 - \Delta\dot{\varphi}_4 = f(\Pi p)$; $6 - \Delta\dot{\varphi}_5 = f(\Pi p)$; $7 - M_д = f(\Pi p)$.



where, $1-\Delta\dot{\varphi}_5 = f(J_5)$; $2-\Delta\dot{\varphi}_4 = f(J_4)$; $3-\Delta\dot{\varphi}_3 = f(J_5)$; $4-\Delta\dot{\varphi}_{43} = f(\Pi p)$; $5-\Delta\dot{\varphi}_4 = f(\Pi p)$; $6-\Delta\dot{\varphi}_5 = f(\Pi p)$; $7-M_д = f(J_д)$; $8-M_2 = f(J_2)$; $9-M_1 = f(J_1)$; $10-M_3 = f(J_3)$; $11-M_4 = f(J_4)$; $12-M_5 = f(J_5)$ when$\Pi_p = 2{,}2\ t/h$.

Fig. 4. Graphical dependences of the change in torque moments and the angular velocity of the rotating shafts of the machine unit.

A significant increase, $\Delta\dot{\varphi}_1$, $\Delta\dot{\varphi}_3$, $\Delta\dot{\varphi}_4$ may cause damage to the cotton fibers and seeds. Therefore, the recommended parameter values are selected from the following conditions: $\Delta\dot{\varphi}_1 \leq 30$ s^{-1}; $\Delta\dot{\varphi}_3 \leq 45$ s^{-1}; $\Delta\dot{\varphi}_4 \leq 45$s^{-1}. It is recommended $n_p \leq 2{,}5$ t/h. it Should be noted that the sawing angular velocity of the saw drums, rotary drum. It is advisable to provide a choice of moments of inertia. On figure 4b graphical dependences of changes in torques and angular velocity of the engine, saw and bar drums and screw are presented. Increasing the moments of inertia of each saw cylinder at a dimensionless value (*J/J*$_{cons}$) from 0,3 to 1,17 the torque on the shaft of the first saw drum at a capacity of 2,2 t/h increases from 16,1 Nm to 35.2 Nm, on the shaft of the second saw drum from 27,1 Nm to 45,2 Nm, and on the shaft of the third saw drum from 30,2 Nm to 49,7 Nm (see Fig. 4B, the curves 9,10,11). This is due to the fact that the main heavy load from the cleaned cotton falls on the third saw drum and then on the second and first saw drums. Accordingly, the range of angular velocity fluctuations in the first saw drum decreases from 71,2 s^{-1} to 27,3 s^{-1}, on the shaft of the second saw drum from 80,2 s^{-1} to 29,3 s^{-1}, and in the third saw drum from 90,2 s^{-1} to 40,3 s^{-1}. This is due to the fact that in the initial cleaning zone, the cotton will be less loosened and steady, so it changes within large limits, but has small values (see Fig. 4b, curves 2,3,4).

The oscillation range $\Delta\dot{\varphi}_5$ decreases from 110 s^{-1} to 48,3 s^{-1} as J_5/J_{5cons} increases to 1,8. This is due to the fact that the bar drums rotate at different angular speeds (60,5 s^{-1} and 63 s^{-1}) and due to the increased load, the oscillation $\Delta\dot{\varphi}_5$ will be greatest. The load on the shaft of the heat-removing auger increases from 11 Nm to 18,2 Nm due to the large value of the moment of inertia [11,12] of the auger and therefore decreases from 34,8 s^{-1} and 11,4 s^{-1}. Recommended values are: J_p=(0,1÷0,11) kgm^2; J_1=(2,2÷2,5) kgm^2; J_2=(1,12÷1,3) kgm^2; J_3=(2,3÷2,5) kgm^2; J_4=(3,1÷3,3) kgm^2; J_5=(2,5÷2,8) kgm^2.

Analysis of the results of comparative tests of the recommended fibrous material cleaner from large litter PT-10.

Production experiments of the PT-10 large-scale cotton cleaner were carried out in comparison with the serial ChX-5M cotton cleaner. The results are presented in table 2.

Table 2

Experimental result

№	Selection of dust litter of the ChX-5M, %				Selection of litter after the PT-10 cleaner, %				The total difference
	Initial	After cleaning	Difference	Efficiency	Initial	After cleaning	Difference	Efficiency	
1	8,7	3,5	5,2	59,7	9,8	3,7	6,1	64,2	4,5

Analysis of the results has been obtained according to table 2 shows that the efficiency of cleaning cotton from litter in the recommended version of the cleaner is higher by 4,5 % than in the serial cleaner.

Conclusions:

It is recommended to improve the design of the fiber material cleaner from large litter. The results of theoretical studies of dynamics of machine unit with blade drive mechanisms, rotary drums and screw area received laws engine working parts. Recommended values of parameters and modes of their movement are defined. Comparative Production tests proved the high effect of cleaning the fibrous material in the recommended cleaner.

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