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EXPERIMENTAL RESULTS ON JUSTIFICATION OF PARAMETERS OF A COTTON CLEANER WITH A NEW DRIVE DESIGN

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ABSTRACT

The article provides an analysis of the state of technical equipment for cleaning fibrous materials, including raw cotton from fine and coarse litter. The scheme of the drive of the cotton-cleaning unit including belt drives with eccentric tension rollers with elastic elements is presented. The results of experimental studies of a belt drive with variable gear ratio, including a composite eccentric tension roller, used in the drive of a cotton-cleaning unit of installation cotton ginning complex (ICGC), are analyzed. On the basis of full-factor experimental studies, the optimal values of the drive parameters have been determined, which allow obtaining a high cleaning effect.

Key words: Cleaner, fibrous material, cotton, drive, saw, peg, belt drive, eccentric, elastic element, angular velocity, torque, full-factor, cleaning effect, layout, frequency.

1. INTRODUCTION

At the present stage of developed textile production, it is important to produce quality products, which depends mainly on the quality of raw materials [1]. Therefore, obtaining high-quality fiber, especially cotton, becomes relevant for the cotton processing industry [2,3]. The production of high quality cotton fiber depends on technological equipment, among which cleaning machines are important. Currently, cotton is cleaned in two directions, cleaning cotton from coarse and fine litter. In production, cotton is cleaned from coarse litter separately, but there is a tendency for cleaning with alternation [3,4], for example, in cleaning units of the ICGC [4]. Due to the imperfection of the design of the working bodies, as well as the incorrect layout of the drive mechanisms, in the ICGC machines it is not possible to obtain the required laws of motion of the working bodies, which does not allow obtaining a high cleaning efficiency. In this regard, we have recommended a new rational layout of the cotton cleaner drive mechanisms of the new machine. [5,6].

Kinematic diagram of a cotton ginner drive with a new layout

To ensure the continuity of the working bodies of the cleaning unit, instead of four electric motors, an electric motor with a power of 11.0 kW, and n = 1000 min^{-1}, and an electric motor for the feed rollers P = 1.5 kW, n = (0÷ 20) min^{-1} are used, as well as a motor for a removable brush drum 2.2 kW, and n = 930 min^{-1}. The recommended diagram of the unit's drive mechanisms is shown in Fig.1.

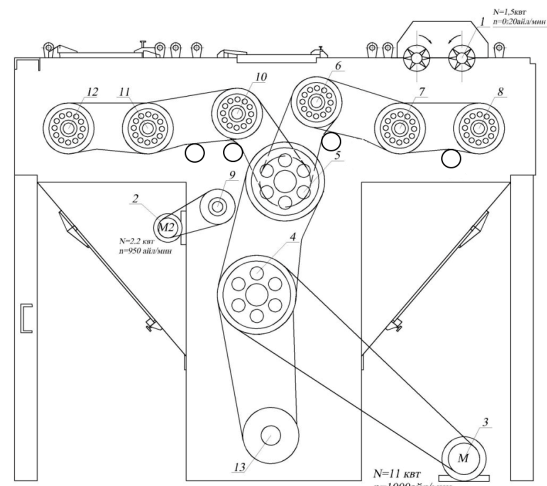


Figure.1. Kinematic diagram of the cotton ginner drive with a new drive layout

A feature of the proposed drive scheme of the unit is the kinematic connection between the main working bodies: saw cylinders 4,5 pegs 7,8,11,12 and brush drums 6,7 waste augers 13. This ensures the work of the working bodies interconnected, as a single flow chain. This allows a decrease in slaughtering, an increase in the cleaning effect, and a decrease in fiber and seed damage.

The analysis of the kinematic diagram of the ICGC machine with the recommended drive shows that belt drives with variable gear ratios are used to provide the required unevenness coefficients of the angular velocities of the picking and transporting drums, allowing the necessary loosening and cleaning of cotton. This is ensured by eccentric idler rollers [7,8,9].

2. RESEARCH METHODOLOGY

Experimental study of the modes of movement of a belt drive with an eccentric tension roller

The experiments were carried out on a special belt drive stand. The parameters were measured according to the electric strain gauge circuit, which is shown in Fig. 2,a and Fig. 2,b shows a general view of the power supply unit for Hall sensors and an E-154 digital converter for connecting to a computer.

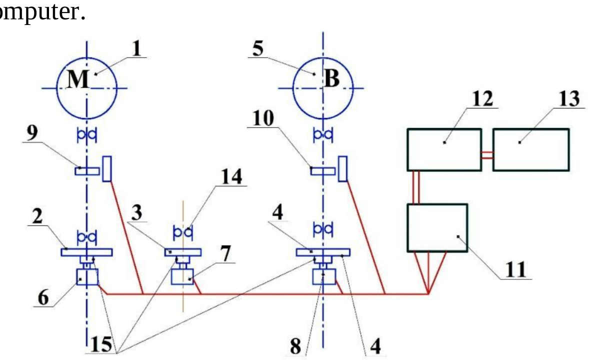


Figure. 2,a. Electric strain gauge circuit

1- electric motor, 2- drive drive pulley, 3- tension roller, 4- driven pulley, 5-brake, 6-7-8- collectors, 9-10 Hall sensors with scrapes, 11 strain gauge amplifier UT-4-1,12- digital converter LTR -154, 13- computer.

Figure. 2,b. A general view of the power supply unit for Hall sensors and a digital converter E-154 for connecting to a computer is presented

A typical oscillogram is shown in Fig.3. At the same time, $\dot{\varphi}_1$, M_1 is marked on the oscillogram - angular velocity and torque on the shaft of the driving pulley; $\dot{\varphi}_2$, M_2 - angular velocity and torque on the driven pulley of a belt drive with an eccentric tension roller.

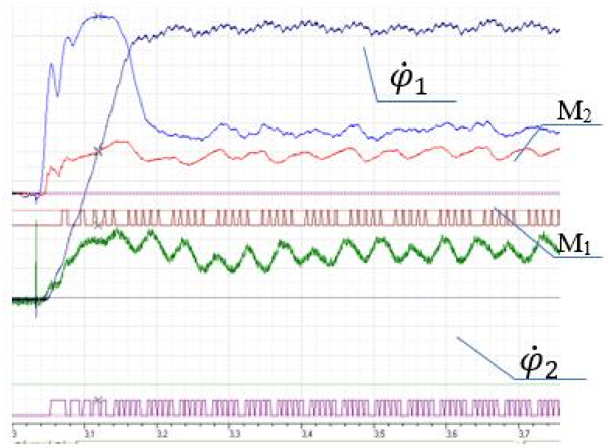


Figure. 3. Oscillogram characterizing the movement of belt pulleys (at $e=2.5\cdot10^{-3}$ m)

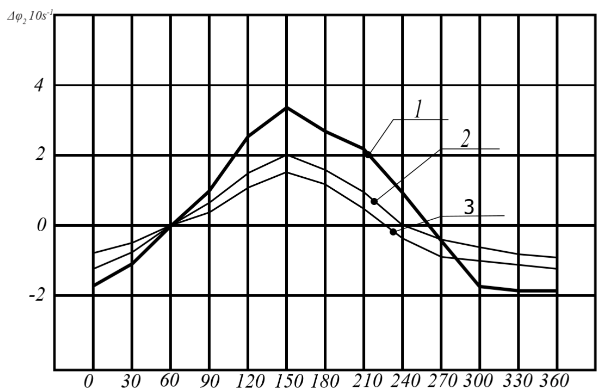
The preliminary belt tension was 150 N. The records were made at an engine speed of 950 rpm, $e=2.5\cdot10^{-3}$ m. The blue line is the torque on the drive shaft and the red line is the torque on the driven shaft. At the same time, the oscillograms show the rotational speeds of the shafts, respectively, the blue sawtooth line for the drive shaft and brown for the rotational speed of the driven shaft. Analysis of the results obtained shows that when the machine is started, the drive pulley slips at the moment of starting. It can also be seen from the graphs that the rotational speed of the driven and driving shafts relative to each other is shifted at the moment of start. This is to say about the presence of slip in the transmission. The acceleration time is 0.95 sec at a main shaft speed of 950 rpm, the time of one revolution of the pulley is 0.065 sec. The results of processing the oscillograms are presented in Table 1.

It should be noted that the gear ratio is taken $U_{1,2}$= 2.9. But, given the variability of the gear ratio, the change in $U_{1,2}$ occurs within (2.7 ÷ 3.1).

When conducting experiments, it is important to determine the range of oscillations of the angular velocity per revolution of the driven pulley at various values of the eccentricity of the tension roller. Figure 4 shows the plotted graphical dependencies.

Table 1. Starting the machine with a tension roller eccentricity e=2.5 · 10^{-3} m

Acceleration time [sec]	Stop time [sec]	Peak load on the shaft after starting, [Nm]	Rotation frequency slave pulley, [Rpm]	Drive shaft rotation speed, [Rpm]	Moment on the driven shaft after acceleration, [Nm]	The moment on the drive shaft after acceleration, [Nm]
0.17	1.55	21.6	391	940	2.25	0.2
0.195	0.68	22.8	379	938	7.65	3.55
0.196	0.59	22.8	396	935	8.5	6.4
0.197	0.375	23.2	401	930	12.8	9.31
0.202	0.325	23.1	428	925	15.1	12.0



where, 1-at e = 3.0 · 10^{-3}m; 2-at e = 2.5 · 10^{-3}; 3-at e = 2.0 · 10^{-3}m.

Figure. 4. Graphs of the dependence of the change in the angular speed of the driven shaft for one revolution of the shaft rotation at various values of the eccentricity of the tension roller

An analysis of the graphs in Fig.4 shows that an increase in the eccentricity of the tension roller to 3.0·10^{-3}m leads to a swing of oscillations of the angular velocity of the driven pulley up to (42÷45) s^{-1}. According to the results of work [10,11,12], to ensure $\Delta\dot{\varphi}_2 \leq (25 \div 30)$ s^{-1}, the recommended values of the tension roller eccentricity are e=2.5·10^{-3} m, at which a high cleaning efficiency of raw cotton is ensured, as in large and small litter.

3. RESULTS OF FULL-FACTOR EXPERIMENTS

As a result of theoretical and experimental studies, the recommended belt drive was used in the transmission mechanism of the ICGC cotton ginner [10,11]. When a new design of a belt drive with a variable gear ratio was applied, installed in the transmission mechanism of a cotton ginner from fine litter, in order to reduce the number of experiments, mathematical planning of experiments was used in the research.

In this case, the following factors are taken as factors influencing the cotton-cleaning effect: the frequency of rotation of the peg drum; eccentricity of the tension roller with elastic element; coefficient of circular stiffness of the elastic roller element. These factors, or input factors, influencing the cleansing effect have been coded.

In this case, X_1 is the frequency of rotation of the peg drum, rpm; X_2-eccentricity of the tension roller with an elastic element, mm; X_3 - coefficient of circular stiffness of elastic element (rubber), N/m.

The values of the output factors are given in Table 2.

Environment input factors; factor X_3 was taken into account on the basis of scientific research.

From experimental studies it was known that the use of an elastic element significantly affects the cleaning effect.

Three types of rubber elasticity were chosen for the experiment. The stage takes into account the circular stiffness of the tension roller rubber bushings. In the experiments, the following rubber grades were used 6308TMKSH and C - (85÷100) Nm/rad; 10-220- (130÷150) Nm/rad and 7317- (190÷230) Nm/rad. The lower value is 84 Nm/rad, the upper -234 Nm/rad. At the same time (150÷200) Nm/rad, good efficiency was observed. In the factors of X_2-eccentricity of the tension roller, 1 mm was chosen as the value, the top -5 mm. The purifying effect was taken as an output factor.

Table 2. Boundaries of factors and intervals of their change

Name of factors	Character coding	The real meaning of factors					Change interval
		-1,682	-1	0	+1	+1,682	
Peg drum rotation frequency, rpm	X_1	387	400	440	480	507	40
Eccentricity of the tension roller with an elastic element, mm.	X_2	0,36	1	3	5	6,4	2
Coefficient of circular stiffness of the elastic roller element (rubber), Nm / rad.	X_3	84	100	150	200	234	50

Based on the calculations, the regression equation is as follows:

$$Y = 41{,}46 + 1{,}087x_1 - 1{,}23x_2 + 0{,}78x_3 - 0{,}29x_1x_2 - 0{,}075x_1x_3 - 0{,}068x_2x_3 - 1{,}47x_1^2 - 1{,}77x_2^2 - 0{,}94x_3^2 \quad (1)$$

The resulting regression equation was tested for adequacy based on Fisher's criterion.

For the sake of clarity of the study, the numerical solution of the regression equation was carried out on a computer using the EXCEL program and graphical dependences of the parameters were obtained (Figs. 5,6,7).

The graphs in Fig.5, built on the basis of regression equations, show that a change in the rotational speed of the peeler drum affects the cleaning efficiency of raw cotton. Graph 1 shows the influence of the input parameters at the lower values x_Σ = 1mm and x_y = 100 Nm/rad on the cleaning effect of cotton. At a frequency of rotation of the peg drum of 400 rpm, the cleaning effect was 36.6%. It was observed that with a further increase in the rotational speed, the cleansing effect also increased. When the rotational speed of the main drum was 456 rpm, the greatest cleaning effect was achieved, 39.2%. With an increase in the rotation frequency from 456 rpm to 480 rpm, the cleaning effect is reduced to 38.8%.

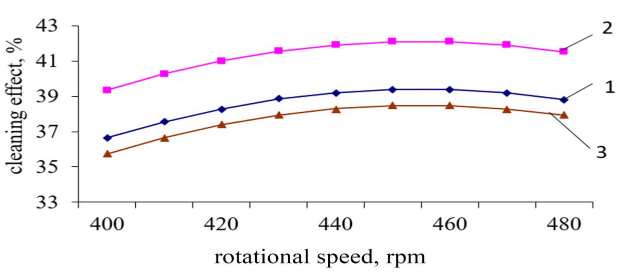


Figure.5. Graphs of changes in the cleaning effect depending on the frequency of rotation of the peg drum

Graph 2 shows the results of changes in the cleaning effect depending on the input factors at their values x_Σ = 3mm and x_y = 150 Nm/rad. At a frequency of rotation of the peg drum of 400 rpm, the cleaning effect was 38.9%. With a further increase in the speed of rotation, the cleaning effect also increases. When the rotational speed of the main drum was 456 rpm, the cleaning effect was greatest at 41.8%. With an increase in the rotational speed to 480 rpm, the cleaning effect decreased and amounted to 41.1%.

Graph 3 shows the results of changes in the cleaning effect depending on the input parameters at the highest values x_Σ = 5mm and x_y = 200 Nm/rad. At the same time, when the rotational speed of the peg drum was 400 rpm, the cleaning effect was the lowest and amounted to 35.8%; with a further increase in the rotational speed of the peg drum, the cleaning effect also increased. At a speed of 456 rpm, the cleaning effect increased to 38.7%. With an increase in the rotational speed to 480 rpm, the cleaning effect was 38%.

Analysis of graph 1 in Fig.5 shows that at a rotational speed of 456 rpm, the cleaning effect reached the highest value of 41.8%.

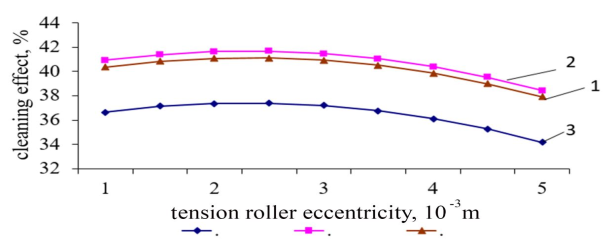


Figure.6. Graphs of the change in the cleaning effect depending on the eccentricity of the tensioning roller with an elastic element

The influence of the eccentricity of the tension roller with an elastic element on the cleaning effect can be seen from the graphical dependence shown in Fig.6. Graph 1 (Fig.6) shows the results of the influence of the input parameters with the following lower values x_1= 400 rpm and x_3 = 100 Nm/rad on the cleaning effect. It can be seen from the graphs that when the eccentricity of the tension roller with the elastic element was 1 mm, the cleaning effect was 40.1%, with the lower values of the input parameters. When the eccentricity of the tension roller with the elastic element was 2.5 mm, the cleaning effect reached the highest value of 39.9%. With an increase in the eccentricity of the tension roller with an elastic element from 2.5 mm to 5 mm, the cleaning effect began to decrease. With a roller eccentricity of 5 mm, the cleaning effect was 38%.

The influence of the input parameters at average values x_1 = 440 rpm and x_3 = 150 Nm/rad can be seen from graph 2 (Fig.6). At the same time, when the eccentricity of the tension roller with the elastic element was 1 mm, the cleaning effect was 40.9%, with an increase in the eccentricity of the roller to 2.5 mm, the cleaning effect also increased to 41.8% and the greatest cleaning effect was observed. With an increase in the eccentricity of the roller from 2.5 mm to 5 mm, the cleaning effect decreased to 38.6%.

The influence of the largest values x_1 = 450 rpm and x_3 = 200 Nm/rad on the cleaning effect is shown in graph 3 (Fig.6). If the eccentricity of the tension roller with an elastic element was 1 mm, the cleaning effect was 36.5%, with an increase in the eccentricity of the roller to 2.5 mm, the cleaning effect also increased and a maximum value was reached, with an increase in the eccentricity of the roller from 2.5 mm to 5 mm the cleansing effect began to decline. When the eccentricity of the tensioning roller with the elastic member was 5 mm, the cleaning effect was the lowest at 34.2%.

When the coefficient of circular stiffness of the elastic element was equal to 100 Nm/rad, the cleaning effect was low and amounted to 36.5% (Fig.7). With an increase in the coefficient of circular stiffness of the elastic element, the cleaning effect increases. When the coefficient of circular hardness has increased to 175 Nm/rad, the cleaning effect reaches 38.4%. With a further increase in the coefficient x_3 to 200 Nm/rad, the cleaning effect decreases and amounts to 38.1%.

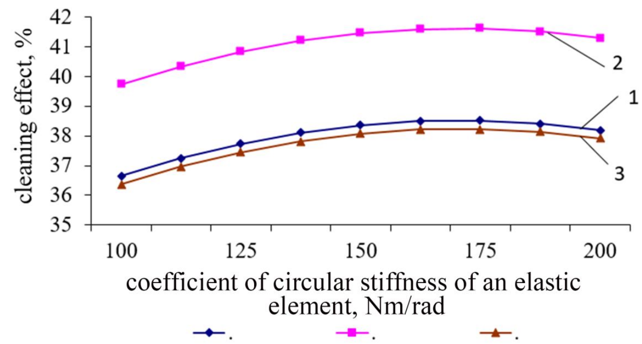


Figure.7. Change of the cleaning effect from changing the coefficient of circular stiffness of the elastic roller element

The effect of changing the coefficient of circular stiffness of the elastic element on the cleaning effect can be seen from the graphs in Fig.7. Graph 1 shows the nature of the change in the cleaning effect depending on the input factors, the values of which are x_1 = 400 rpm and x_2= 1 mm.

Graph 2 (Fig.7) shows the results of changes in the cleaning effect at average values of the input factors x_1 = 440 rpm and x_2 = 3mm. With a coefficient of x_2 100 Nm/rad, the cleaning effect was low and amounted to 39.8%. With a further increase in the coefficient of circular hardness x_3, the cleaning effect increased. When the coefficient of elasticity was equal to 175 Nm/rad, the cleansing effect rose to 41.8%. However, with a further increase in the x_3 coefficient to 210 Nm/rad, the cleaning effect decreased and amounted to 41.3%.

Graph 3 (Fig.7) shows the dependences of the change in the cleaning effect at high values of the input factors: x_1 = 480 rpm and x_2 = 100 Nm/rad, the cleaning effect was low and amounted to 36.4%. With an increase in the coefficient X_3 to 175 Nm/rad, the cleansing effect also increased, and with this coefficient x_3 of the elastic element, the greatest cleansing effect was obtained. Analysis of the graphical data shows that with an increase in the x_3 coefficient to 200 Nm/rad, the cleaning effect decreased and reached 36%.

From the above it follows that the coefficient of circular stiffness of the elastic element affects the cleaning effect. The greatest cleaning effect was achieved with a coefficient of circular hardness of 175 Nm/rad and this value is optimal.

Based on the results from full-factor experiments, it follows that when using belt drives with an eccentric tension roller with a rubber sleeve in the drives of cleaning machines with their recommended parameters, a high cleaning effect can be achieved. Consequently, the optimal values of the parameters of the cleaning machine were found: the rotation frequency of the peg drum 456 rpm, the eccentricity of the tension roller with the elastic element 2.5 m, the coefficient of circular stiffness of the elastic element 175 Nm/rad. With these parameters, the greatest cleaning effect was achieved, which was 41.8%.

4. CONCLUSION

The results of experimental studies were obtained for the regularities of measuring angular velocities and torques on the driving and driven pulleys of the belt drive with eccentric tension rollers used in the drive of the cotton ginner. On the basis of a full-factor experiment, the optimal values of the parameters of the purifier with an effective drive arrangement were determined.

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