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Development of an Effective Design and Justification of the Parameters of a Screw Conveyor for Transporting and Cleaning Cotton Linters

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ABSTRACT: The article presents a new effective structural scheme and the principle of operation of the conveyor with a screw with a zigzag profile. Based on the solution of the problem of system dynamics, taking into account the dynamic mechanical characteristics of the engine, inertial, elastic-dissipative parameters, as well as technological loads from the transported and cleaned cotton lint, regularities of movement of the working body are obtained, the basic parameters of the conveyor are substantiated. Based on production comparative tests of the recommended conveyor, the efficiency of its use in production is substantiated.

KEY WORDS: Conveyor, Screw, Zigzag Profile, Fibrous Material, Lint, Transportation, Cleaning.

I.INTRODUCTION

Screw conveyors are widely used for transporting various materials, in particular bulk and fibrous materials. In the cotton processing line, lint is cleaned of impurities with a screw cleaner. Known screw conveyor containing a stationary groove, the lower part of which is in the form of a half cylinder, closed with a lid on top, and a drive screw mounted in the groove along its axis in bearings mounted on the groove. The movement of cargo along the trough is carried out by turns of a rotating screw [1,2]. The disadvantage of this analogue is the high energy consumption and the possibility of slaughtering the load in the gutter with an increased supply of material.

The design of the conveyor of fibrous materials contains a trough, the lower part of which has the shape of a half cylinder, closed with a lid on top. Annular bandages are attached to the groove in the lower cylindrical part, by means of which the groove is mounted on rollers so that the groove can oscillate around its axis. The rollers abut against the end planes of the annular band on the gutter. The chute for the possibility of oscillation is suspended on bearings on the screw shaft. The lid has an inlet on the left side, and the trough has an outlet on the right side. The disadvantage of this design is the inability to remove from the total mass of transported cotton seeds weed impurities released as a result of screw movement. As a result, the separated weed impurities enter the technological linter machine and strongly pollute the resulting lint product [4].

It should be noted that in existing screw conveyors during the transportation of fibrous materials, especially cotton, due to insufficient loosening of the material, there is not enough litter. In addition, due to insufficient friction between the screw surface and the fibrous material, they lag during transportation, which leads to additional mechanical damage to the fibrous material (cotton and their waste). The interaction of the helical surface on the fibrous material occurs monotonously in one direction, with a constant driving force, which does not ensure their cleaning efficiency. In order to ensure sufficient loosening of the transported fibrous material, to increase the cleaning effect and the required transportation performance, the screw conveyor design has been improved by increasing the contact area, increasing the friction force, as well as changing the values of the direction of interaction of the screw with the transported fibrous material [5,6].

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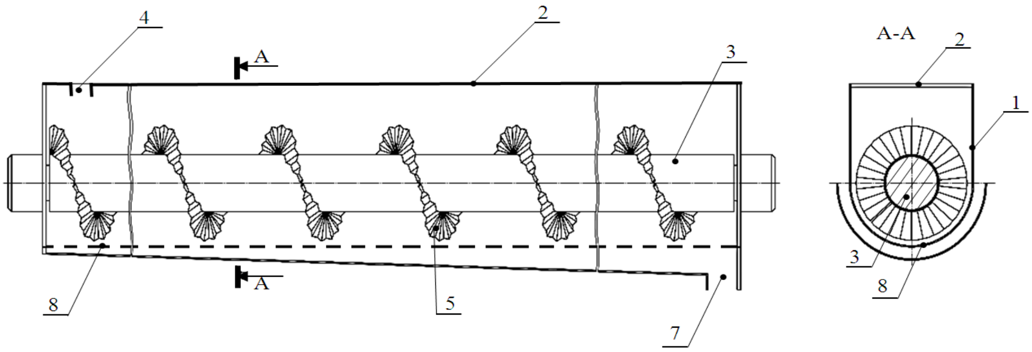
II. RESEARCH METHODS

The screw conveyor contains a groove 1, the lower part of which has the shape of a half cylinder, closed with a cover 2 on top. Inside the groove 1, screw 3 transporting material along its axis (Fig. 1). On top of the groove 1 there is an inlet 4, and in the end, at the bottom there is an outlet 7. The lower working part of the groove 1 is made in the form of a mesh surface 8. The working surfaces of the screw 3 are made in a zigzag shape 5 having triangular protrusions and depressions. The height of the triangles 5 of the screw 3 is chosen equal to the average size of the cotton seed, (40 70 mm). The ribs 6 of the triangles 5 of the screw are mutually parallel, and when winding onto the shaft, they are directed along the radius of the screw 3.



Sweep of the detail 3
Enlarged

Fig. 1. Screw conveyor for transporting and cleaning fibrous material

Screw conveyor operates as follows. The fibrous material (raw cotton, fibrous waste) is fed into the groove 1 through the inlet 7 in the lid 2 and, when the screw 3 is rotated, is advanced by sliding along the groove 1 by the zigzag (triangular) working surface 5 of the rotary screw 3 pulled through to the outlet 8.

Zigzag (triangular protrusions and depressions) 5 the shape of the working surfaces of the screw 3 acts on the seeds and volatiles of cotton with different strength and direction of force, which leads to an additional release of cotton, this allows the efficient allocation of litter from the fibrous material (cotton). Weed impurities extracted from the fibrous material fall out through the openings of the mesh surface 8 of the trough 1 and are discharged into the self-exhaust through the hole.

The recommended design of the screw conveyor allows efficient transportation of fibrous materials, increased productivity, provides the necessary cleaning effect.

III. RESEARCH RESULTS

The design scheme of the water of the screw conveyor is adopted in the form of a three-mass system: 1-mass consists of an engine rotor, a driving belt pulley; 2-mass of the driven pulley and reduced masses of gears of the gearbox, as well as the leading part of the coupling; 3-mass includes the leading part of the coupling and screw. The design scheme is shown in Fig. 2

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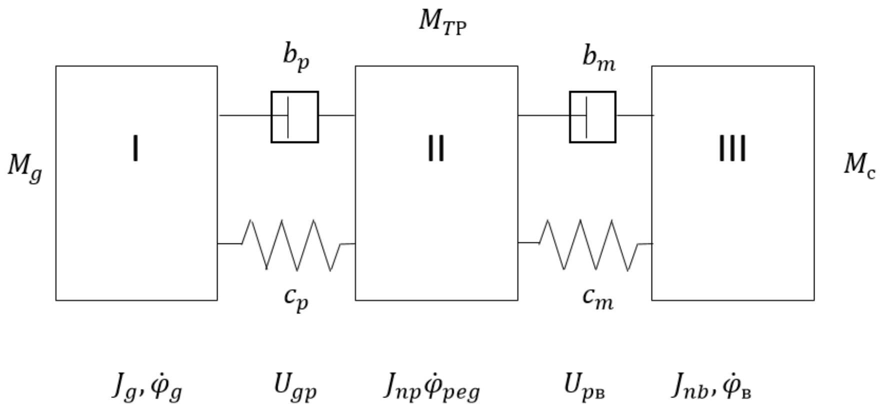

Fig. 2. Design diagram of machine unit with conveyor screw drive mechanism for transportation and cleaning of cotton lint.

The system of differential equations describing the movement of elements of a screw conveyor has the form [7]:

$$\begin{aligned}
&M_{\text{д}} = f(\dot{\varphi}_{\text{д}});\\
&J_{\text{д}}\ddot{\varphi}_{\text{д}} = M_{\text{д}} - \text{в}_p \Delta\dot{\varphi}_{\text{д}p} - C_P \Delta\varphi_{\text{д}p};\\
&J_{np}\ddot{\varphi}_{p\text{ед}} = u_{\text{д}p}(\text{в}_p \Delta\dot{\varphi}_{\text{д}p} + c_p \Delta\varphi_{\text{д}p}) - \text{в}_{\text{м}} \Delta\dot{\varphi}_{\text{мв}} - c_{\text{м}} \Delta\varphi_{\text{мв}} - M_{mp}; \qquad (1)\\
&J_{n\text{в}}\ddot{\varphi}_{\text{в}} = u_{p\text{в}}(\text{в}_{\text{м}} \Delta\dot{\varphi}_{\text{вм}} + c_{\text{м}} \Delta\varphi_{\text{вм}}) - M_{m\text{в}} - M_c;\\
&\Delta\varphi_{\text{д}p} = \varphi_{\text{д}} - \varphi_{p\text{ед}} u_{\text{д}p};\ \Delta\varphi_{\text{мв}} = \varphi_{p\text{ед}} - u_{p\text{в}}\varphi_{\text{в}};\\
&M_c = M_1 + M_0 \sin\omega_{\text{в}} t \pm \delta M_1
\end{aligned}$$

$J_{\text{д}}$, J_{np}, $J_{\text{кв}}$ - reduced moments of mass inertia respectively on the motor shaft, on the input shaft of the gearbox, on the screw shaft; c_p, $c_{\text{м}}$, b_p, b_m - coefficients of circular stiffness and dissipation coefficients of belt drive and coupling; M_1, M_0, δM_1 - components of the technological load from the transported and cleaned cotton lint, $M_{m\text{в}}$ - moment of friction on the screw shaft. [8].

The numerical solution of system (1) was performed on a PC using standard programs with the following parameter values: asynchronous motor Y132S-8, $P=2.2$ *kW*; $n=710$ *rpm*; $u_{dr}=1,27$; $u_{rv}=20$; $J_d=1.12$ kgm^2; $J_{pr}=2.89$ kgm^2; $J_{pv}=7.14$ kgm^2; $c_r=(200\div250)$ *Nm/rad*; $b_r=(5.0\div5.5)$ *Nms/rad*; $c_m=(400\div420)$ *Nm/rad*; $b_m=(9.5\div10.5)$ *Nms/rad*; $M_1=(46\div65)$ *Nm*; $M_0=(5.5\div10)$ *Nm*; $M_t=(35\div45)$ *Nm*; $\delta M_1 = (0.05 \div 0.07) M_1$.

Based on the solution of the system of differential equations (1) under the following initial conditions, t=0; $\dot{\varphi}_d = 0$; $\dot{\varphi}_{red} = 0$; $\dot{\varphi}_b = 0$; $M_d = 0$; $M_c = 0$. Regularities of changes in the angular velocities of the rotor of asynchronous motor, a screw conveyor, as well as torque on the motor shaft are obtained. Received regularities of change $M_d, \dot{\varphi}_d$ and $\dot{\varphi}_b$ are shown on fig. 3. The analysis shows that with the increase in the load M_1 from the transported and cleaned lint within $(45 \div 65)$ Nm, the angular speed of the motor rotor actually remains unchanged, and its decrease is insignificant. Besides, the range of oscillations in the angular speed of the rotor of the engine also varies within insignificant limits. However, the decrease in the angular speed of the screw with a zigzag profile will be noticeable. So, at $M_1=45$ *Nm* $\dot{\varphi}_{\text{в}}$ decreases to 27.2 s^{-1}, and at the load 65 Nm $\dot{\varphi}_{\text{в}}$ decreases to 25.9 s^{-1}. In this case, the amplitude of the oscillations $\Delta\dot{\varphi}_{\text{в}}$ increases from (1.2÷1.4) s^{-1} to (3.0÷3.8) s^{-1}. Increase in the amplitude of the oscillations positively affects the effect of transportation and cleaning of the lint due to their additional shaking.

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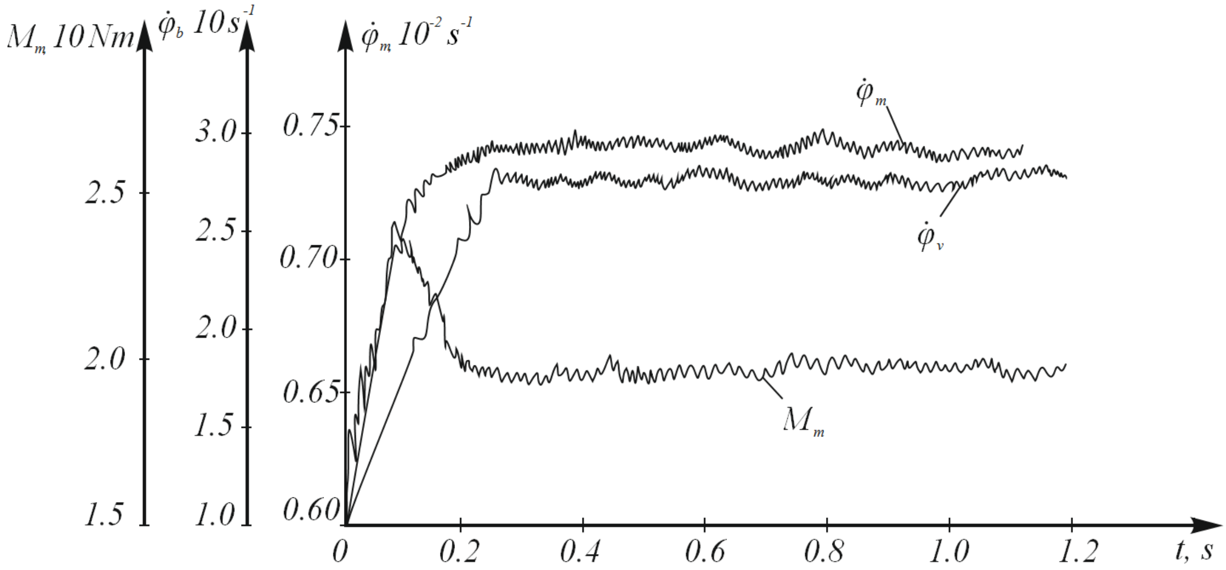
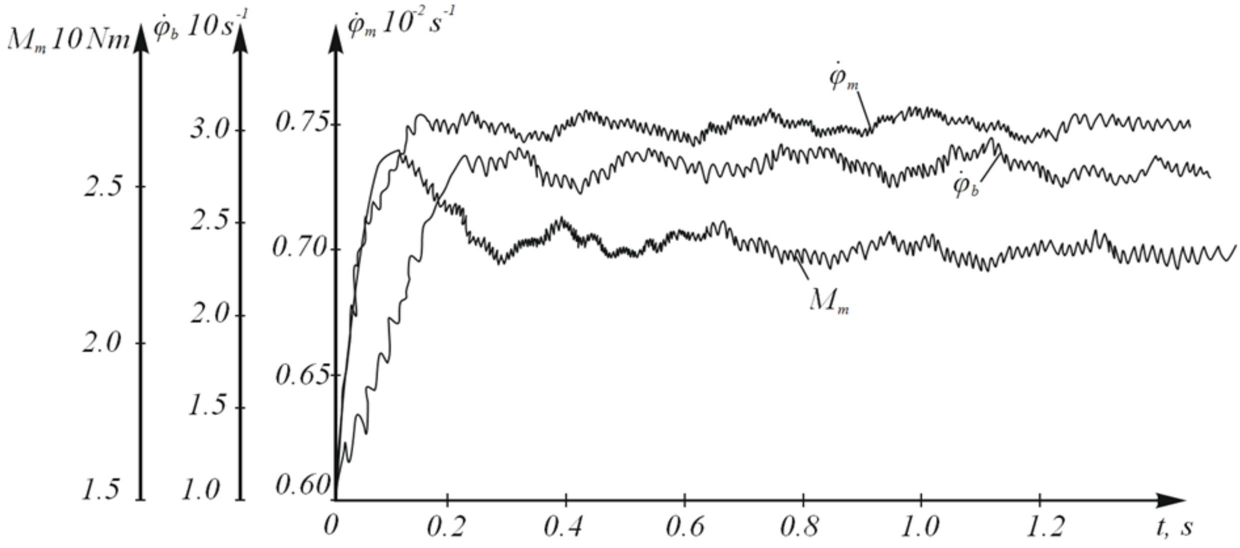


at $Mc = 45H\text{м} + 6{,}55\sin\omega t \pm \delta M$,



at $Mc = 65H\text{м} + 8{,}5\sin\omega t \pm \delta M$,

Fig. 3. The patterns of change in the angular velocity of the rotor of the engine, the screw shaft, as well as the torque on the motor shaft.

Based on the reasonable parameters of the working elements of the screw conveyor, a prototype was designed and manufactured.

Tests of the recommended design of the conveyor with a zigzag screw surface were carried out in comparison with the existing version in the conditions of the cotton mill. The analysis of the test results shows that when using a screw with a zigzag profile, the emitted fluff is reduced (3–3.5) times, and the damage to the seeds (skin) of cotton is also reduced. The excretion of fine litter is increased (2.0 ÷ 2.5) times compared with the existing conveyor. The overall cleaning effect of cotton lint is increased by (6.0 ÷ 10.5)% in the recommended conveyor relative to the serial machine.

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IV. CONCLUSION

Offers an efficient conveyor with a screw with a zigzag profile. On the basis of theoretical studies, the laws of motion of the rotor of the engine and the conveyor screw are obtained, the parameters and modes of movement of the system are justified. Experiments revealed that the recommended conveyor allows a significant increase in the effect of cleaning and transportation of lint.

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