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DYNAMIC ANALYSIS OF FLUTTER CONVEYOR AND CLEANING SCREW CONVEYOR MACHINE UNIT

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Abstract. In this article, the results of the dynamic analysis of the machine assembly, which includes the mechanisms of the working bodies of the proposed oscillating, mesh surface with curved holes, screw conveyor with a wavy surface are presented. Graphs of dependence of the obtained driver, reducer and screw movement laws and loadings on grid parameters are given. Based on the analysis, the recommended values of the parameters of the screw conveyor machine unit are based.

Keywords. Conveyor, screw, mesh surface, fluff, electric drive, belt drive, clutch, shaft, torque, rigidity, dissipation, resistance, radial velocity, law of change

Mathematical models of machine assembly

The dynamic model is based on the recommended screw conveyor machine unit arrangement with four masses. In this case, the first mass is the rotor of the electric drive, the second mass is the mass of the reducer connected to the drive and combined into one structure, the third mass is the mass of the coupling, and the fourth mass is the mass of the screw [1, 2, 3].

This machine assembly can be viewed as a four-mass dynamic system (Fig. 1).

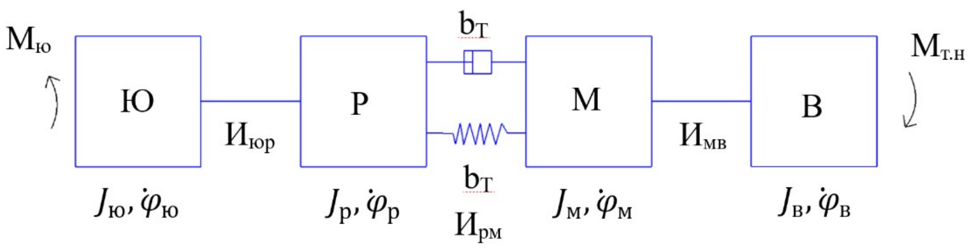


Fig. 1. Dynamic analysis of screw conveyor machine assembly.

A mathematical model representing the movement of the proposed screw conveyor machine assembly was created in the form of a system of differential equations [4, 5, 6]:

$$\frac{\omega_0-\dot{\varphi}_{yu}}{\omega_0}=\frac{s_k}{2M_k}M_{yu}+\frac{\dot{M}_{yu}}{2\omega_0 M_2}; \qquad J_{yu}\ddot{\varphi}_{yu}=M_{yu}-M_{yup};$$

$$J_P\ddot{\varphi}_P=I_{yup}M_{yup}-C_T(\varphi_P-U_{PM}\varphi_M)-v_T(\dot{\varphi}_P-U_{PM}\dot{\varphi}_M);$$

$$J_M\ddot{\varphi}_M=U_{PM}C_T(\varphi_P-U_{PM}\varphi_M)+U_{PM}B(\dot{\varphi}_P-U_{PM}\dot{\varphi}_M)-M_{mv};$$

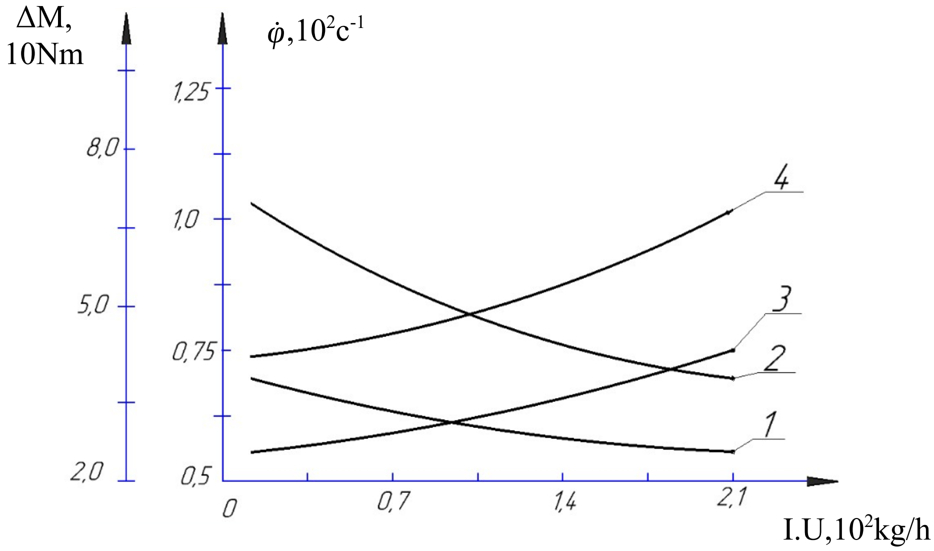
$$J_B\ddot{\varphi}_B=U_{MB}M_{MB}-[M_1+M_0\sin\omega t\pm\Delta M_B].$$

Numerical solution of the resulting system of differential equations was carried out at the initial values of the parameters [7, 8]:

Electric drive (motor-reducer) R67 DRS100M4; $n_{yu}=1400$ rpm; $n_p=¿110$ rpm; $U_T=\frac{D_2}{D_1}=\frac{160\,mm}{100\,mm}=1{,}6$; $n_M=n_v$=68,75rpm; $U.y$=(180÷200)kg/hour; J_{yu}=0,018kgm^2; J_R=0,361kgm^2; J_M=0,31kgm^2; J_V=4,63 kgm^2; C_T=(250÷300)Nm/rad; b=(4,5÷5,0)Nm/rad; f_c=50Hz; N=3,0kW; U_0/U_1=220V/380V; M_k=38Nm; λ=1,6; s_n=0,128; p=2; ω_s=3/4s^{-1}; ω_0=157s^{-1}; π=3,14; M_1=(48÷70)Nm; M_0=(3,8÷6,3)Nm; ΔM_B=±(0,05÷0,07)M_{tk}; M_{rm}=(35÷45)Nm.

The numerical solution of the problem was carried out using a special computer program [9]. The results were recorded as the laws of change of the electric drive rotor, reducer, clutch, screw shaft radial speeds and loads in the machine assembly.

Using the obtained laws, graphs of the interconnection of machine unit parameters were constructed. In particular, Fig. 2 shows the graphs of changes of radial speeds and torques on the output shaft, clutch and screw shafts of the proposed lint-carrying-cleaning screw conveyor reducer depending on the performance.

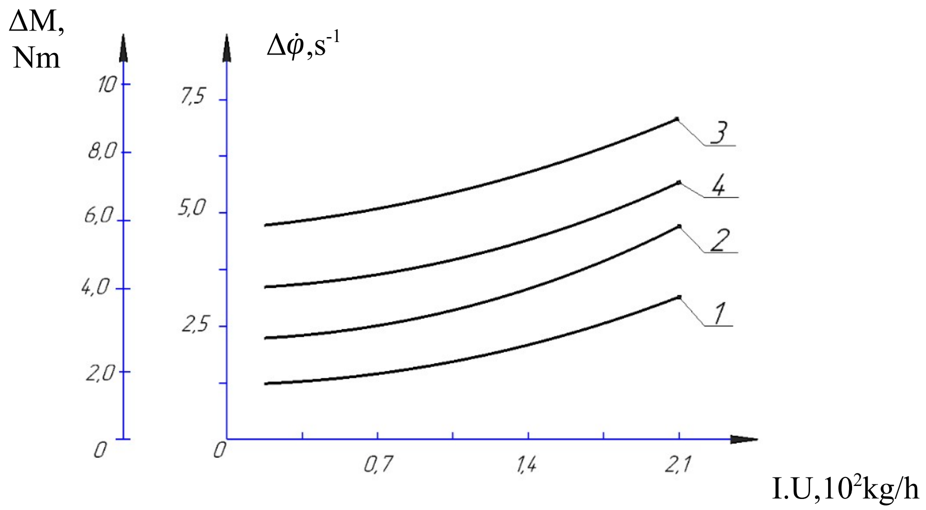


1-$\dot{\varphi}_v = \dot{\varphi}_m ¿ f(I.U)$; 2-$\dot{\varphi}_r ¿ f(I.U)$; 3- $M_v = M_m = f(I.U)$; 4- $M_r = f(I.U)$;

Fig. 2. Variation line graphs of radial velocities and torques on the output shaft, clutch and screw shafts of the recommended fluff carrier-cleaner screw conveyor reducer depending on the performance.

Correspondingly, when the conveyor productivity increases from 35 kg to 200 kg per hour in terms of cotton fluff being transported, the radial speed of the screw shaft $\dot{\varphi}_v$ decreases from 72.5s^{-1} to 57.3s^{-1} in the nonlinear connection, the radial speed of the drive pulley on the reducer outlet shaft is 107.5s^{-1} from 74s^{-1} can be seen to decrease in the non-linear bond (Fig. 2, graphs 1, 2), but torque values increase. In particular, it can be seen that the torque M_v on the conveyor screw shaft increases from 36.2 N/m to 64.5 N/m, while the M_r values increase from 22 N/m to 44.3 N/m (Fig. 2, graphs 3, 4).

According to the analysis, when the productivity increases to 200 kg/h, the values of $\Delta\dot{\varphi}_v$ increase from 4.82s^{-1} to 7.42s^{-1} in a non-linear pattern, and the angular velocity oscillation range of the belt drive pulley $\dot{\varphi}_r$ values increase from 3.09s^{-1} to 5.29s^{-1}.



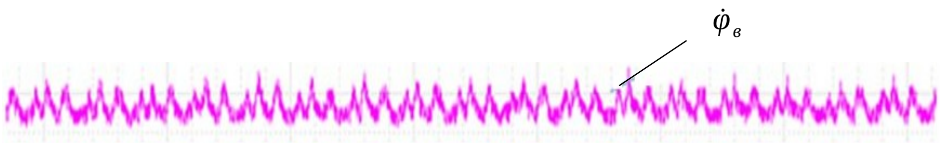
1- $\Delta M_r = f(I.U)$; 2- $\Delta M_v = f(I.U)$; 3-$\Delta \dot{\varphi}_r = f(I.U)$; 4-$\Delta \dot{\varphi}_r = f(I.U)$;

Fig. 3. Dependence graphs of the vibration ranges of the torques on the screw conveyor's screw and the outlet shaft of the reducer.

Also, the range of torque fluctuations on the screw shaft - ΔM_v values increase from 2.2 Nm to 5.18 Nm, while ΔM_r values increase from 1.8 Nm to 3.76 Nm in nonlinear connection. (Figure 3, graphs 1-4). So, when the productivity does not exceed (180÷200)kg/h, the recommended values are: $\dot{\varphi}_v$=(55÷60) s^{-1}; $\dot{\varphi}_r$ =(80÷90)s^{-1}; $\Delta\dot{\varphi}_v$=(6,0÷6,5)s^{-1}; $\Delta\dot{\varphi}_r$=(4,5÷5,0)s^{-1}. In this M_v=(66÷70)Nm; M_r =(40÷45)Nm is provided.

It should be noted that radial velocity fluctuations also depend on the belt drive's rotational singularity-dissipative properties. Laws obtained as a result of research are presented. In particular, Fig. 4 shows the laws of radial speeds change in the electric drive (reducer), clutch and screw shaft of the machine unit depending on the change of belt transmission rotational speed and load.

According to the analysis of the obtained laws, the increase in the uniformity of the belt transmission leads to a sharp decrease in the values of $\Delta\dot{\varphi}_v$. Also, if the random component of the technological resistance is high ($\Delta M_v \pm (0,2 \div 0,25) M_{tq}$) the form of vibration of $\Delta\dot{\varphi}_v$ also changes.



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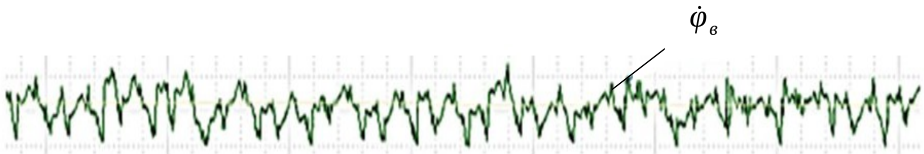
c_T=350Nm/rad; M_1=48Nm; M_1=3,8Nm; ΔM_v=±(0,2÷0,25) M_{tq}



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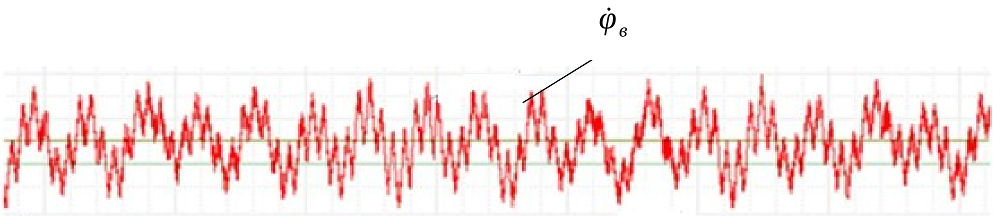
c_T=250Nm/rad; M_1=60Nm; M_0=5,4Nm; ΔM_r=±(0,2÷0,25) M_{tq}

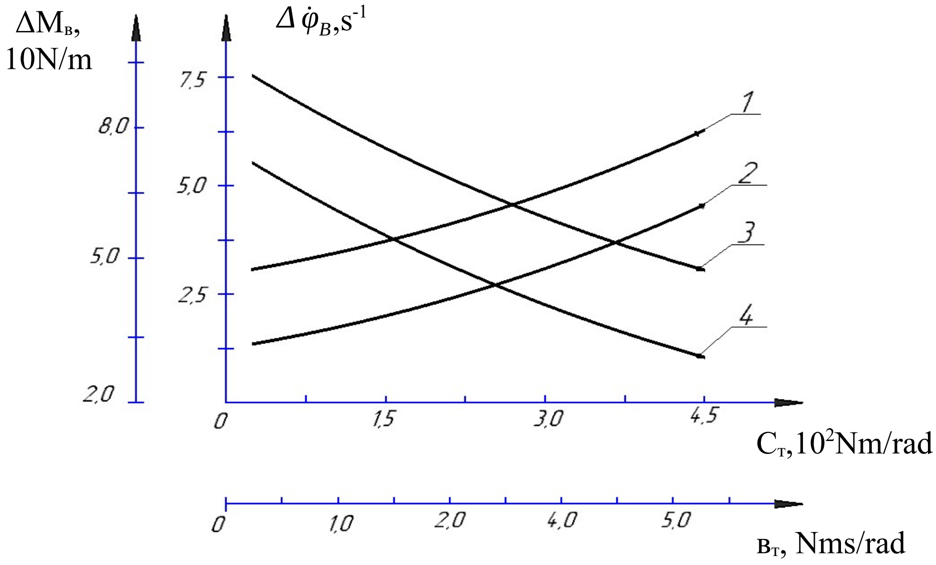


в

c_T=200Nm/rad; M_1=70Nm; M_0=6,0Nm; ΔM_r=±(0,2÷0,25) M_{tq}

Fig. 4. Machine unit electric drive (reducer), clutch and radial speed in the screw shaft, belt transmission, rotational speed and laws of change depending on the change of load.

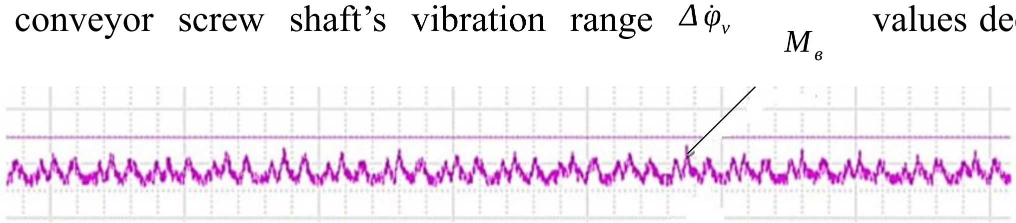
In this case, the harmonic organizer of the technological resistance is almost imperceptible. Fig. 5 presents graphs of the dependence of the rotation speed and dissipative coefficients of the belt transmission on the torque and radial speed of the screw shaft included in the proposed fluff-carrying-cleaning screw conveyor machine assembly.



1-$M_v=f(c_T)$; 2- $M_v=f(b_T)$; 3-$\Delta\dot{\varphi}_r$ ¿ $f(c_T)$; 4-$\Delta\dot{\varphi}_r$ ¿ $f(b_T)$;

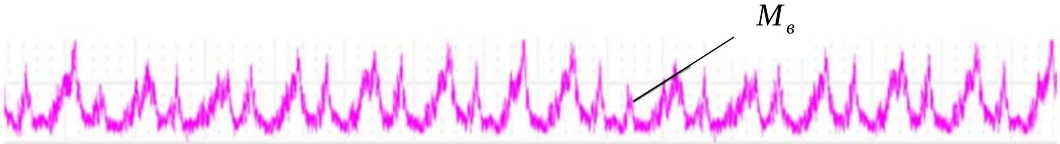
Fig. 5. Dependence graphs of the torque on the screw shaft and the radial speed of the vibration range of the belt drive rotation uniformity and dissipative coefficients in the recommended fluff-carrying-cleaning screw conveyor machine assembly.

When the built-up graphic patterns are analyzed, when the rotational speed of the belt drive increases from 100 Nm/rad to 450 Nm/rad, the radial velocity of the conveyor screw shaft's vibration range $\Delta\dot{\varphi}_v$ values decrease from 7.35 s^{-1} to 3.9 s^{-1}, and the torque values on the shaft increases from 49.8 Nm to 52.8 Nm. Also, when the rotational dissipation coefficient of the belt transmission decreases from 5.42 s-^{1} to 1.14 s^{-1}, the torque M_v values increase from 34.5 Nm to 60.5 Nm in a non-linear manner (Figure 5, graphs 1-4). It is known that the increase in the radial speed of the screw has a positive role in the transportation and cleaning of the cotton fluff. But, an excessive increase in $\Delta\dot{\varphi}_v$ will increase additional vibrations and fluff damage. So, to ensure that $\Delta\dot{\varphi}_v$=(6,0÷6,5) s^{-1}; $\Delta\dot{\varphi}_r$=(4,5÷5,0) s^{-1} is in the range of recommended values for belt drive S_t=(280÷340)Nm/rad; It is advisable to choose v_T=(3,3÷3,8)Nm/rad. Figure 6 shows the laws of torque changes on the shafts of the working bodies of the proposed screw conveyor machine unit.



M_1=48Nm; M_0=3,8Nm; c_T=300Nm/rad; ΔM_v=(0,2÷0,25) M_{tq}

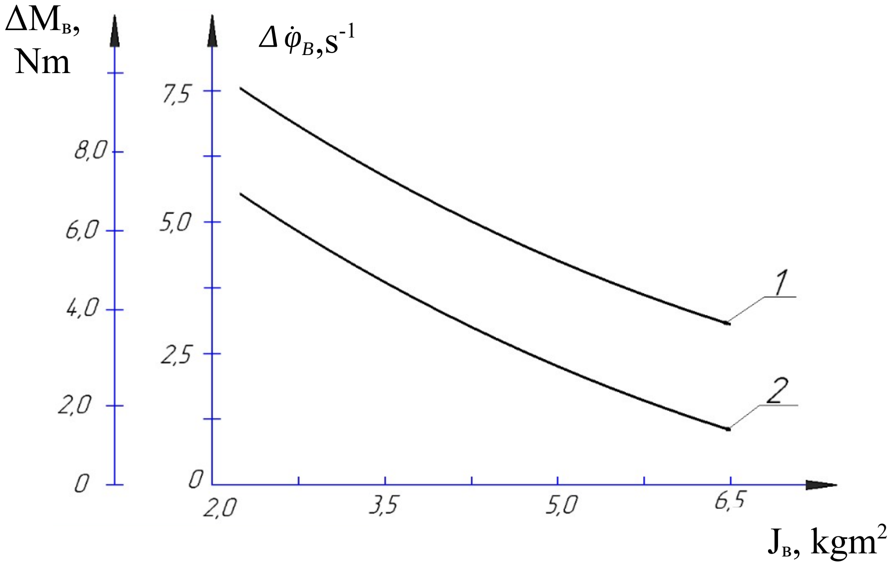
M_1=60Nm; M_0=5,2Nm; c_T=250Nm/rad; ΔM_v=(0,2÷0,25) M_{tq}



M_1=70Nm; M_0=6,0Nm; c_T=200Nm/rad; ΔM_v=(0,2÷0,25) M_{tq}

Fig. 6. The laws of changing torques on the shafts of the working bodies of the recommended screw conveyor machine unit

It is known [10, 11, 12] that their inertial moments are selected at sufficient values to adjust the movement of rotating shafts. The obtained laws show that the increase in the inertial moment of the conveyor screw shaft significantly reduces the range of torque oscillations, and the values of $\Delta\dot{\varphi}_v$ decrease accordingly. Based on these regularities, connection graphs were constructed. Fig. 7 shows the graphs of the dependence of the values of torque and radial velocities in vibration on the wavy surface of the main working body of the proposed screw conveyor on the screw shaft and its moment of inertia.



1-$\Delta\dot{\varphi}_v = f(J_v)$; 2-$\Delta M_v = f(J_v)$;

Fig. 7. Dependence graphs of torque and radial velocities on the screw shaft on the wave surface of the main working body of the recommended screw conveyor.

The inertial moment of the screw working body in the machine unit has a large value. To reduce it requires a reduction in length or diameter. But the sufficient distribution of $\Delta\dot{\varphi}_v$ and ΔM_v depends on the justification of the values of J_v. When the values of the inertial moment of the conveyor screw shaft are increased from 2.71 kgm^2 to 6.35 kgm^2, the torque range on the screw shaft decreases from 6.05 Nm to 2.15 Nm in the non-linear connection, the range of radial velocity oscillations $\Delta\dot{\varphi}_v$ values from 7.52 s^{-1} to 5, 05 s^{-1} decreases. Therefore, to ensure that the screw radial speed does not exceed the vibration range (6.0÷6.5) s^{-1}, it is appropriate to choose the values of the moment of inertia in the range J_v=(3,8÷4,5) kgm^2.

Conclusion. The article presents the results of the dynamic analysis of the machine assembly, which includes the mechanisms of the working bodies of the fluff-carrying and cleaning screw conveyor. The recommended values of the system parameters were determined as a result of the analysis of the change laws of the angular speed and loads of the screw and the connection graphs.

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