PROPER FREQUENCIES AND AMPLITUDES OF SMALL VIBRATIONS OF BELT DRIVE PULLEYS

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Abstract: The article provides a method for determining the natural frequencies and the amplitude of small oscillations of the driving and driven pulleys of the belt drive in relation to the drive of the cleaning section from the small debris of the unit. Analytical expressions and calculation results are obtained in the form of graphical dependencies of changes in natural frequencies and amplitudes of small vibrations of transmission pulleys. Based on the analysis of the constructed graphical dependencies, the values of the moments of inertia of the driving and driven pulleys, as well as the value of the gear ratio for the drive of the cotton cleaner from fine litter, are recommended.

Keywords: Belt drive, belt lengthening, pulley, natural frequency, amplitude, moment of inertia, moment resistance, gear ratio.

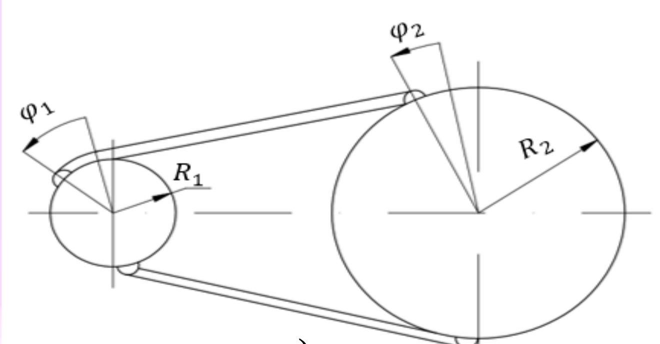
Introduction

It is known that in all the main technological machines of primary processed cotton in their drives, belt drives are used [1]. In this case, it is important to ensure the necessary modes of movement of the working bodies. Uneven rotation of working bodies with a certain frequency and amplitude will directly affect the technology and product quality [2]. Therefore, it is advisable to determine the natural frequency and amplitude of small oscillations of the belt drive pulleys, depending on the transmission parameters.

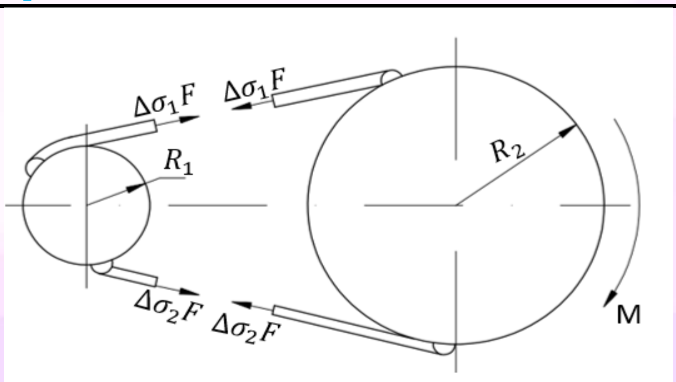
Method for determining the natural frequencies and the amplitude of small vibrations of the pulleys of the design transmission.

In the recommended belt drive, due to the eccentricity of the tension roller, the driven pulley will rotate with a variable angular velocity [1, 2]. It is important to determine the values of natural frequencies and amplitudes of small vibrations of belt pulleys. In technological machines, the driven pulley is mainly associated with the working body. Therefore, the vibrations of the driven pulley to some extent affect the law of motion of the working body. Vibrations in the drive pulley also affect the movement of the machine's electric motor.

In Fig. 1, a) shows a diagram of a belt drive considering the lengthening of the driving and driven transmission branches. According to this scheme, we have [3]:



a)



b)

Fig. 1. Belt drive diagram: where, a is the scheme of lengthening the transmission branches, b is the scheme of the action of forces in the transmission branches

According to this scheme, we have [3]:

$$\Delta l_1 = \frac{D_1}{2}\varphi_1 - \frac{D_2}{2}\varphi_2$$

$$\Delta l_2 = -\frac{D_1}{2}\varphi_1 + \frac{D_2}{2}\varphi_2 \qquad (1)$$

In this case, the additional stresses ($\Delta G_1, \Delta G_2$) of the belt in the branches are determined from the expressions,

$$\Delta l_1 = \frac{\Delta G_1}{E} l\,,\ \Delta l_2 = \frac{\Delta G_2}{E} l \qquad (2)$$

where, l is the length of the belt, m; E - modulus of elasticity, Pa; φ_1, φ_2 - angular displacements of the driving and driven pulley. In Fig. 1, *b)* shows a diagram of a belt drive with additional forces acting on the pulleys.

Differential equations of forced vibrations of transmission pulleys are as follows:

$$J_1\ddot{\phi}_1 + \frac{D_1}{2}F(\Delta G_1 - \Delta G_2) = M_d$$

$$J_2\ddot{\phi}_2 + \frac{D_2}{2}F(\Delta G_2 - \Delta G_1) = M_r \qquad (3)$$

where, D_1, D_2 is the diameter of the driving and driven pulleys, *m*; M_d, M_r- driving moment and moment of resistance, *Nm*; J_1, J_2 - moments of inertia of transmission pulleys, *kgm²*.

Considering (1) and (2) and substituting them into (3), after some transformations, we obtain

$$\ddot{\phi}_1 + p_{11}\phi_1 + p_{12}\phi_2 = \frac{M_d}{J_1}$$

$$\ddot{\phi}_2 + p_{21}\phi_1 + p_{22}\phi_2 = \frac{M_r}{J_2} \qquad (4)$$

where $p_{11} = \frac{2R_1^2 EF}{lJ_1}$; $p_{12} = -\frac{2R_1R_2EF}{lJ_1}$; $p_{21} = -\frac{2R_1R_2EF}{lJ_2}$; $p_{22} = \frac{2R_1^2 EF}{lJ_2}$.

From (4) the natural frequencies of the pulleys

$$p_1 = 0; \;\; p_2 = \left[\frac{2EF}{l} \left(\frac{R_1^2}{J_1} + \frac{R_2^2}{J_2} \right) \right]^{\frac{1}{2}} \quad (5)$$

In this case, the zero root in (5) corresponds to a small rotation of the pulleys in one direction, at which additional stresses in the belt do not arise.

The amplitudes of small, forced vibrations of the driving and driven pulleys are determined from the expressions,

$$A_{\phi_1} = \frac{M_r p_{11}}{J_1[(p_{11} - \omega^2)(p_{22} - \omega^2) - p_{12}p_{21}]}$$

$$A_{\phi_2} = \frac{M_r(p_{11} - \omega^2)}{J_2[(p_{11} - \omega^2)(p_{22} - \omega^2) - p_{12}p_{21}]} \quad (6)$$

In this case, the total stresses in the branches of the belt drive will be,

$$G_1 = G_0 + \frac{E}{l}(R_1\varphi_1 - R_2\varphi_2)$$

$$G_2 = G + \frac{E}{l}(R_2\varphi_2 - R_1\varphi_1) \quad (7)$$

Numerical solution and analysis of results

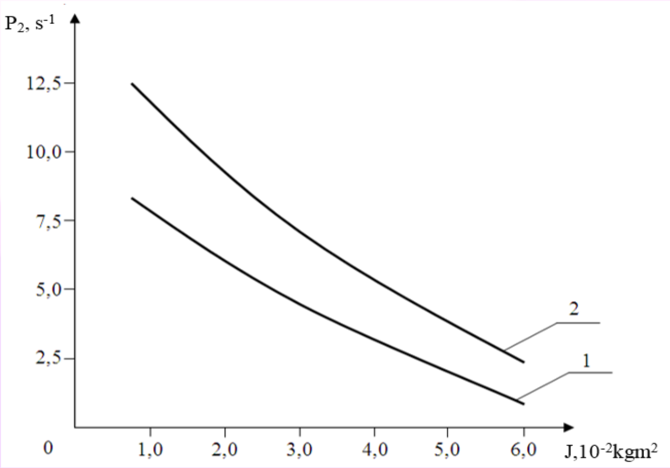
The numerical solution of the problem was made for the belt drive used in the drive of the cleaning section from the fine litter of the cotton cleaning unit. Initial parameter values: $R_1 = 1{,}5 \cdot 10^{-3}$ m, $R_2 = 2{,}0 \cdot 10^{-3}$ m, $l = 12{,}5 \cdot 10^{-3}$ m, $J_1 = 0{,}02$ kgm², $J_2 = 0{,}033$ kgm², $E = 10^3$ kg/sm², $F = 2{,}5$ sм², $G_0 = 22$ kg/sм², $\omega = 0{,}75\,p_2$.

In Fig. 2 shows the graphical dependences of the change in the natural frequency of angular vibrations of the driven pulley of the transmission from the change in the moments of inertia of the pulleys (a) and the gear ratio of the belt drive (b).

The resulting graphical dependencies are nonlinear (see Fig. 2). With an increase in the moment of inertia of the driven pulley from $0{,}75 \cdot 10^{-2}$ kgm² до $5{,}9 \cdot 10^{-2}$ kgm² natural frequency p_2 decreases from 12,5 s^{-1} до 2,4 s^{-1}, and with an increase in the moment of inertia of the drive pulley, the natural frequency decreases to 1.19 s^{-1}. With an increase in the gear ratio of the belt drive, the natural frequency p_2 also increases in a nonlinear manner. The natural frequency p_2 increases significantly with the cross-sectional area of the belt $2{,}5 \cdot 10^{-4}$ m².

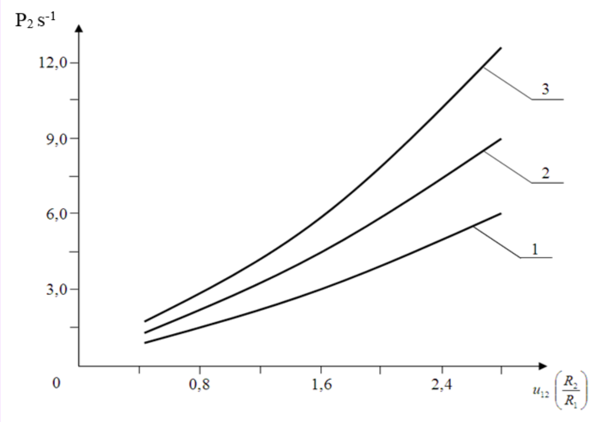
So, with an increase in u_{12} from 0.5 to 2.8, the natural frequency of small angular vibrations of the driven pulley increases to 12.35 s^{-1} with a belt section F = $2.5 \cdot 10^{-4}$ m², and with F = $3.0 \cdot 10^{-4}$ m² p_2 only goes up to 6.15 s^{-1}.

Therefore, to increase the frequency of small oscillations in the working bodies of technological machines, it is advisable to increase the frequency of oscillations due to the choice of F. For the section for cleaning cotton from fine litter, it is recommended F = (2.0 … 2.5)$\cdot 10^{-4}$ m² at u_{12} = 1,5 … 2.0. Accordingly, the recommended values of the moments of inertia of the pulleys are: $J_1 = (0{,}5 \ldots 1{,}2) \cdot 10^{-2}$ kgm², $J_2 = (1{,}35 \ldots 2{,}8) \cdot 10^{-2}$ kgm².



a)

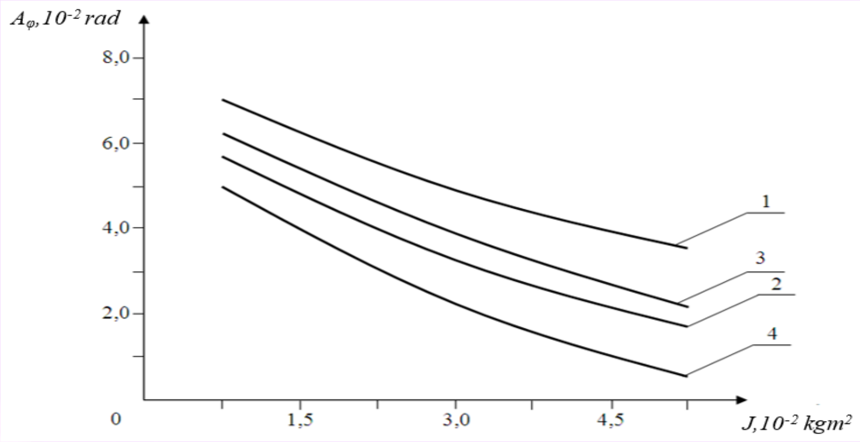
where *1*- $p_1 = f(J_1)$; *2*- $p_2 = f(J_2)$



b)

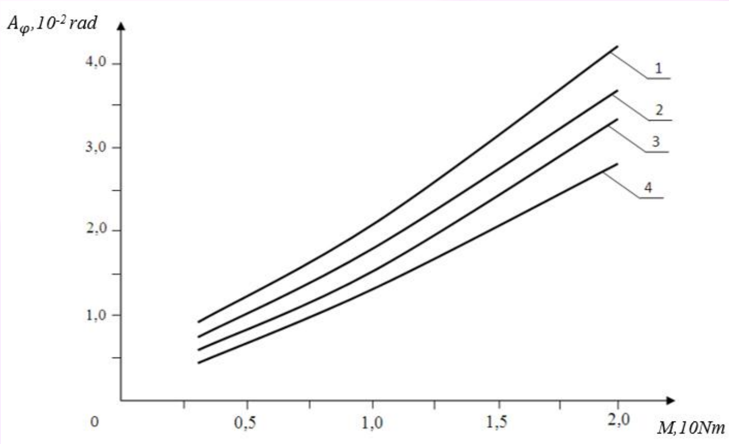
On the 1st $F = 2{,}5 \cdot 10^{-4}$ m²; 2nd $F = 2{,}75 \cdot 10^{-4}$ m²; 3rd $F = 3{,}0 \cdot 10^{-4}$ m²

Fig. 2. Graphical dependences of the change in the natural frequencies of the pulleys vibrations on the change in the moments of inertia of the pulleys (a) and the gear ratio of the transmission (b)



1, 3- A_{φ_1} ; 2, 4- A_{φ_2} ; 1, 2- On the $A_\varphi = f(J_1)$; 3, 4- On the $A_\varphi = f(J_2)$

Fig. 3. Dependences of the change in the amplitude of small angular vibrations of the belt drive pulleys on the variation in the values of the moments of inertia of the driving and driven pulleys



1, 3- A_{φ_1} ; 2, 4- A_{φ_2} ; 1, 2 On the $A_\varphi = f(M_o)$; 3, 4- On the $A_\varphi = f(M_d)$

Fig. 4. Graphical dependences of the change in the amplitude of small angular oscillations of the pulleys on the variation in the amplitude of the moment of resistance and driving moment

It should be noted that a change in the driving moment on the shaft of the driving pulley will also lead to certain angular vibrations of the transmission pulleys (see Fig. 4, graphs 3,4). The recommended values for the cotton cleaner are Nm, at which the required angular vibration of the driven pulley with the required frequency is ensured.

Conclusions:

1. Formulas for calculating natural frequencies and amplitudes of small vibrations of belt pulleys.
2. Based on the numerical solution of problems, graphical dependencies are built changes in natural frequencies and amplitudes of small vibrations of pulleys from changes in moments of inertia and gear ratio.
3. The recommended values of the moments of inertia and transmission the number of the belt drive used in the drive of the cotton cleaning section from fine litter.

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