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RESEARCH OF RIGIDITY OF TOOTHEDS OF THE TOOTHED BELT IN CONDITIONS OF THE DYNAMIC LOADING

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Abstract

The article results of experimental researches of rigidity of tootheds of a toothed belt within the limits of zones of a deficient profile gearing are presented by transmission of capacity.

Keywords: toothed-belt transmission, rigidity of tootheds, deficient profile gearing, intense-deformed condition.

ИССЛЕДОВАНИЕ ЖЁСТКОСТИ ЗУБЬЕВ ЗУБЧАТОГО РЕМНЯ В УСЛОВИЯХ ДИНАМИЧЕСКОГО НАГРУЖЕНИЯ

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Реферат

В статье представлены результаты экспериментальных исследований жёсткости зубьев зубчатого ремня в пределах зон неполнопрофильного зацепления при передаче мощности.

Ключевые слова: зубчато-ременная передача, жесткость зубьев, неполнопрофильное зацепление, напряженно-деформированное состояние.

The rigidity of belt teeth is one of the parameters, defining the distribution of loading in a toothed-belt gearing, and, hence, defining the load carrying capacity and the operational resource of transmission.

As a result of the theoretical research of the complex stress condition of the elements of a toothed-belt transmission it is established that the deformation of belt teeth is defined by the stresses of a bearing strain, shear and bending. Solving the problem of the theoretical definition of the deformation of a belt tooth at the known combination of force factors and mechanical properties of a belt, the ratio of the deformations, making a total tangential deformation, is determined. It is established that in the condition of full gearing at $\beta_p = \beta_\omega$ the shear deformations make up the main quantity.

The theoretical research of the stress-strained state of a belt tooth, carried out by the author [1], is also devoted to the analysis of the tooth, which has completely input in gearing of a belt. Considering the problem, the author notes that finding of the analytical solution is extremely complicated, since the problem refers to the type of the non-classical mixed contact problems of the theory of elasticity.

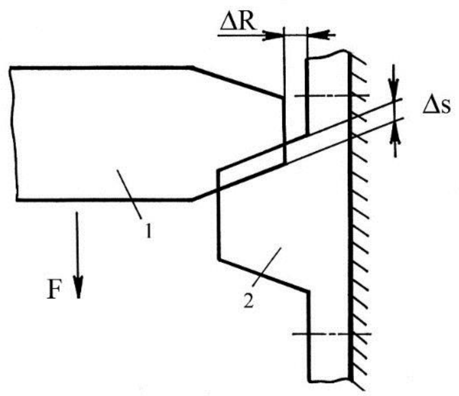
The researches of the stress-strained state with the application of the method of finite elements [2–5] are also known. However, the results of these researches are presented in the form of the diagrams of stress in the material of a belt tooth, received on the basis of numerous approximations. It is not possible to find the value of the total tangential deformation of a tooth with their help, especially when a tooth is in the state of the incomplete profile gearing. Thus, we can come to the conclusion, made in the work [6], that it is expedient to define the value of the rigidity of teeth experimentally.

At the experimental determination of EZ the following dependence is used (Fig.1):

$$EZ = \frac{F}{\Delta s}, \tag{1}$$

where F – the effort on a belt tooth;

Δs – the tangential deformation of a tooth.



1 – penetrator; 2 – belt tooth

Figure 1 – Loading of a belt tooth

It is established that the value EZ is better to be expressed in relation to the module of shear of rubber of the tooth G, defined by the hardness. In this case:

$$EZ = \frac{G}{a_z}, \tag{2}$$

where a_z – the empirical factor: a_z = 0,230...0,239 – for the belts with the module m = 1...10 mm; a_z = 0,251...0,264 – for the belts *MXL–XXH* [7].

The values EZ, received in such a way, cannot be used for the description of the deformation of teeth in the conditions of the incomplete gearing that is characteristic of the angles ψ_1 and ψ_2 (Fig.2). It is possible to assume that in such conditions the value EZ is less than its value at full gearing, since the centroid of the effort F is displaced to the tip of a belt tooth.

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This conjecture is proved implicitly by the researches of EZ in the conditions of the incomplete profile gearing, characterized by the existence of the radial clearance ΔR [8]. The behavior of EZ within the limits of the angle ψ_1 is described in the work [9], however, the influence of the phase of gearing within the limits of the angle ψ_2 on EZ is not established. Due to the opposite direction of loading, applied to the tooth in the zones ψ_1 and ψ_2, different dependences of the change of EZ (within the limits of the given angles) appear. The experimental researches were conducted to prove the given hypothesis.

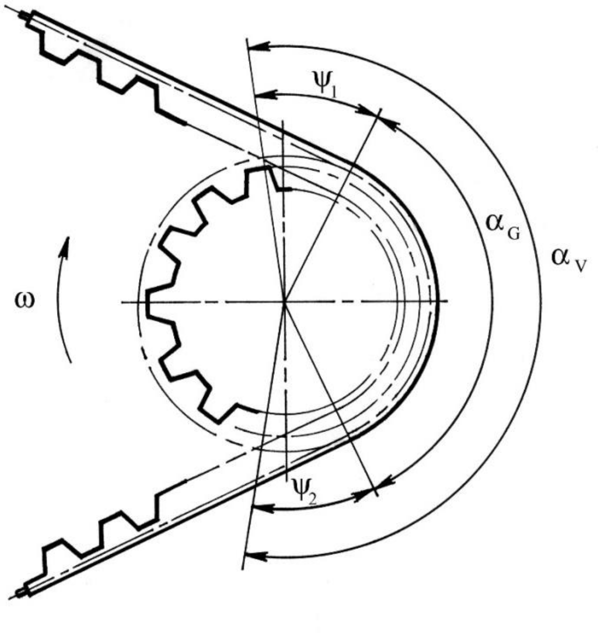


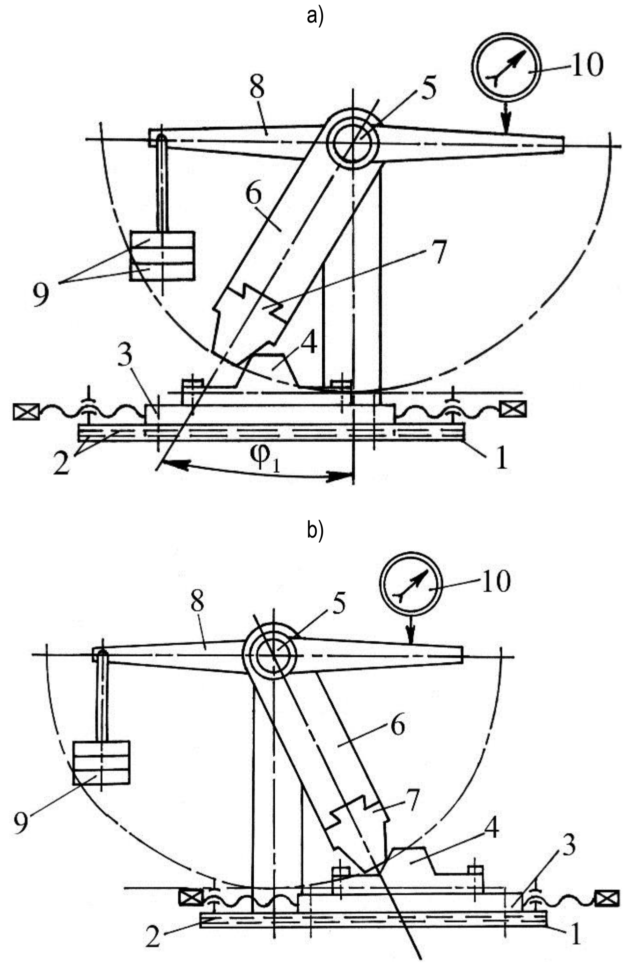
Figure 2 – Scheme of the interaction of a toothed belt with a pulley (ψ_1, ψ_2 – the angles of an input of teeth in gearing and an output from it accordingly – the zones of an incomplete profile gearing of teeth)

The toothed belts with the following parameters: 1) m = 7 mm; z_p = 71; B_p = 32 both 50 mm and 2) m = 3 mm; z_p = 48; B_p = 16 mm with hardness of teeth HS = 58,6; 64,2; 74,3; 85,2 relative units are the objects of the researches. The belts are made by the method of diaphragm vulcanizations and of pressing by rigid elements, made of rubber mixture 1453 with the use of kapron fabric facing of the art.56320, gum-dipped (№ 420).

The values of the angles ψ_1 and ψ_2 vary within the limits, corresponding to $z_ш$ = 8...30. The effort on the examined tooth changes within the limits 0...F_{max}, where $F_{max} = 2[F_t] / z_ш$. $[F_t]$ according to [10] for m = 3 and 7 mm are taken as10 and 45 N/mm. The replication of carrying out of the experiments is 7 at their reliability 0,95 [11].

The developed special stand (Fig.3) is used for the experimental researches. It consists of the frame 1 with the guides 2, in which the movable carriage 3 is established. The fragment of the examined belt 4 is fixed on the carriage 3. In the top part of the frame 1 the axis 5 with the lever of the variable length 6 with the penetrator 7 on the end, is placed. The profile of the penetrator corresponds to the profile of the pulley tooth. The lever 8 is positively connected with the lever 6. The lever 8 is equipped with a set of loads 9 and the displacement indicator 10 in the form of the indicator of a clock type with the division value 0,01 mm.

At the given value $\psi_{1(2)}$, defined from the value $z_ш$, the tooth of the belt (by moving of the carriage 3) is fixed at the distance X from the axis of symmetry of the pulley, corresponding to the demanded arc of traverse of the pulley φ_2 within the limits of 0...$\psi_{1(2)}$. The length of the lever 6 is adjusted up to the value $R = mz_ш / 2$. After that the penetrator 7 is engaged with the tooth of the examined belt. Consequently, increasing the effort on the tooth of the belt from 0 to F_{max} by means of the loads 9, the angular displacement $\Delta\varphi_2$ of the lever 6 is registered.



a) input in gearing; b) output from gearing

Figure 3 – Stand for the research of rigidity of belt teeth

The value of the tooth rigidity for each effort F_i, acting on it, is determined by the formula:

$$EZ_i = \frac{F_i}{Rtg\left(\Delta\varphi_2\right)}. \quad (3)$$

Discretely changing the distance X that corresponds to getting of different phases of gearing within the limits of the angles $\psi_{1(2)}$, we make loading of a belt tooth. As a result of the researches the dependences EZ of the phase of gearing, the module of a belt and hardness of its teeth are received (Fig.4).

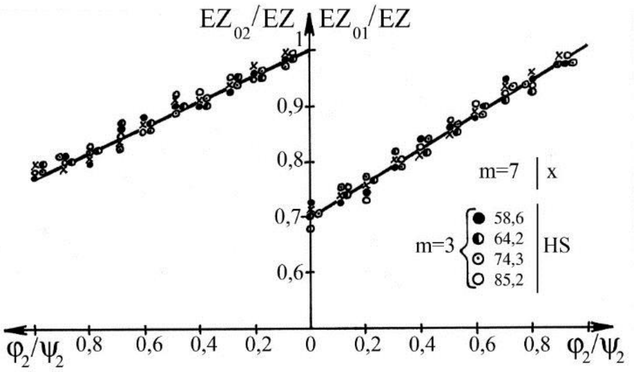


Figure 4 – Rigidity of belt teeth at different phases of an input in gearing and an output from it

The dependences EZ of the phase of a pulley turn within the limits of the angles of the input in gearing and the output from it can be expressed as the empirical equations:

$$EZ_{01} = EZ\left(0,7 + 0,3\frac{\varphi_2}{\psi_1}\right), \quad (4)$$

$$EZ_{02} = EZ\left(1 - 0,23\frac{\varphi_2}{\psi_2}\right). \quad (5)$$

The analysis of the dependences shows the unequal influence of the angles ψ_1 and ψ_2 on the rigidity of teeth. At the equal change of ψ_1 and ψ_2 the increase of EZ_{01} is 1,3 times more intensive than the reduction of EZ_{02}. At the same time the limiting values of EZ_{01} at φ_2 / ψ_1 = 0 are 10 % less than EZ_{02} at φ_2 / ψ_2 = 1. It is explained by the fact that the initial contact of teeth at their input in gearing takes place in the zone of the tip of the belt teeth. The disconnection of teeth at the output, as a rule, occurs in the middle part of a belt tooth.

Thus, the empirical dependences, allowing to define the rigidity of the belt teeth in the zones of the incomplete profile gearing, are received.

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