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Improving the contact strength of V-belt pulleys using plastic deformation

Marchenko D.D[*]., Matvyeyeva K.S.

Mykolayiv National Agrarian University, Ukraine
**E-mail: marchenkodd@mnau.edu.ua*

Abstract

The article presents the results of a study of the contact strength of V-belt pulleys when they work on contact collapse. To increase the wear resistance and contact strength of the tribological conjugation, a method for rolling around the side surfaces of pulleys with a roller and a device for its implementation are proposed. The proposed method and device can increase the wear resistance of the pulleys, and hence the durability of 1.6 ... 2.1 times.

Key words: contact strength, plastic deformation, hardening, wear resistance, V-belt pulley, roughness.

Introduction

The most responsible nodes of the mechanisms are V-belt drives. Currently, the problem of increasing the durability of V-belt drives of equipment operating in dusty environments remains very acute. To a large extent, this problem can be solved by improving the quality of the working surfaces of V-belt pulleys [1].

The large depth of the groove of the pulley profile with a small width of the groove creates difficulties in finishing it throughout the entire depth of the profile. The low vibration resistance of the machine – cutter – part system does not allow obtaining the required surface roughness corresponding to = 0.16 ... 1.25 μm (GOST 2789 - 73). Most often, roughness = 10 ... 40 microns. To obtain the desired roughness of the conical surface, the pulleys are subjected to surface plastic deformation by rolling around the rollers [2, 3].

In order to ensure intensive deformation of the metal of the surface layer with relatively small rolling forces (5 - 6 kN), acceptable on medium metal cutting machines, a method of rolling around a conical cantilever roller was applied.

Research technique

The kinematics of the known method of rolling a part of a complex profile with a roller consists in rotating the roller around its axis and in translating it along the profile of the surface to be rolled. With a variable curvature of the part profile, as the roller is fed, the reduced curvature at the contact point changes, and this leads to a decrease in the quality of the rolled surface, since the condition for optimizing the breaking in force is violated. The radius of curvature of the roller rp with the known method of running in must be less than the smallest radius of curvature of the concave section of the part profile, which limits the allowable feed rate and thereby reduces the productivity of the process.

The method of rolling around the envelope is that the contact point of the roller with the part as it moves to a new position moves along the part in the process of mutual enveloping of their profiles. Thus, rolling in occurs both in the rolling plane – the cross section of the roller, and in the feeding plane – its axial section [4]. The profile of the roller during rolling around the envelope can generally have variable curvature, consistent with the curvature of the part so that at each point the optimal conditions for their contact are ensured. In particular, with this method, the same reduced contact curvature of the roller with the part can be provided, which allows the use of a constant working force, sufficiently large rolling feeds and guarantees the surface quality and high performance of the process. In addition, rolling around the envelope allows you to more evenly load the working surface of the rollers due to the gradual displacement of the point of contact with the part along the axial section profile. Moreover, this displacement is ensured when rolling parts with a straight generatrix, for example, screw surfaces [5, 6]. The value of this fact is especially great for increasing the resistance of small diameter rollers.

Depending on the shape of the rolling profile, in order to optimize the rolling mode, either variable-profile rollers or structural schemes are used that provide the necessary variable effort along the profile depending on the reduced curvature of the roller and the part at their contact point. Running in according to the method of enveloping with a cantilever roller is used for finishing the side walls of streams of V-belt pulley pulleys. An analysis of the operation of V-belt drives during the running-in period of the surface of the side walls of pulley streams with the initial surface roughness corresponding to the parameter Rz = 20 - 40 µm shows that at this time there is intense wear on the surface of the belts and the working surface of the pulleys. At the end of the running-in stage, the surface roughness of the streams corresponds to the parameter Ra = 0.16 - 0.32 µm [7]. Such a surface roughness on the side walls of streams cannot be obtained when machining with polishing cutters on turning and carousel machines due to the low vibration resistance of the machine-tool-component system.

Research results

The kinematics of the known method of rolling a part by a roller consists in rotating the roller around its axis and in translating it along the profile of the rolling surface from position 1 to position 1' (Fig. 1, a).

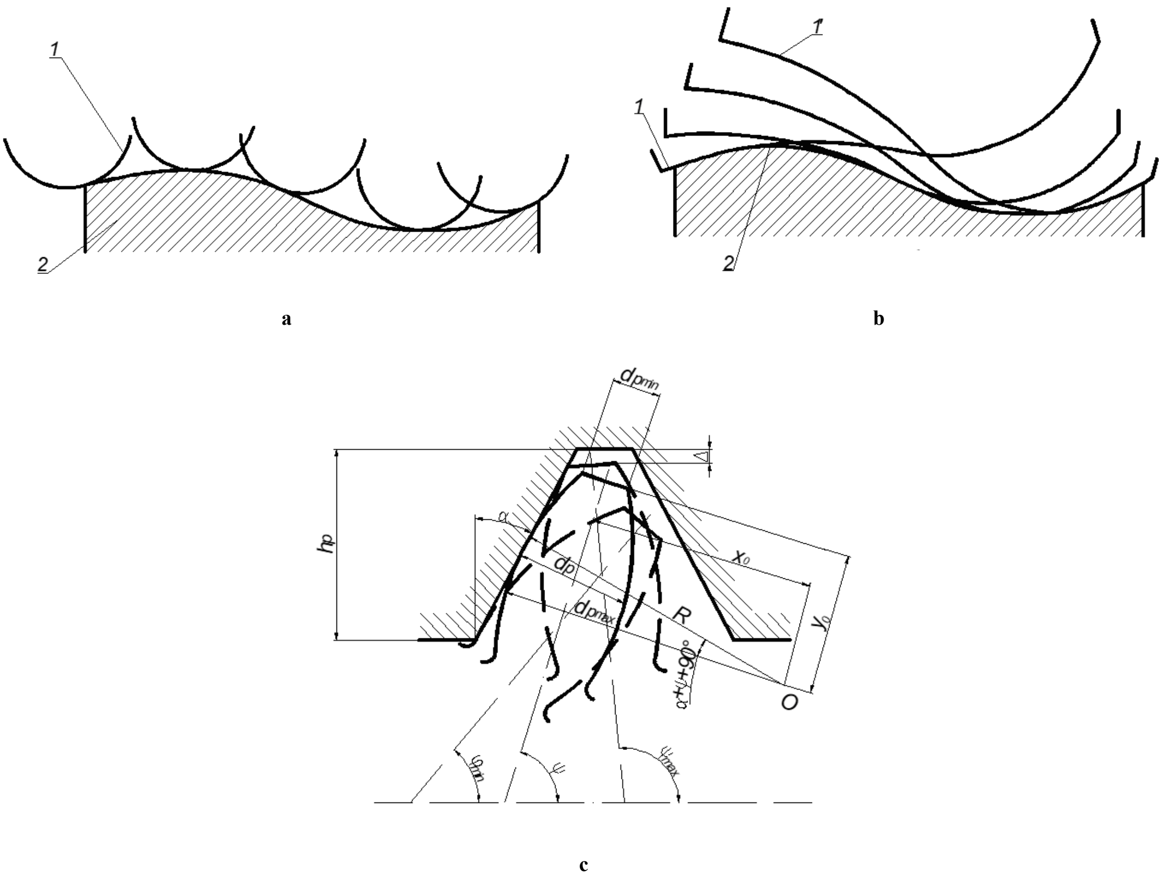

Fig. 1. Schemes for rolling parts with rollers with longitudinal feeds (a) and rounding (b), as well as the calculation scheme for the reduced roller diameter and rounding angle (c):
1 – roller;
2 – detail

With a variable curvature of the part profile, as the roller is fed, the reduced curvature at the contact point changes: $1/R_{np} = 1/R_{\text{д}} + 1/r_p$ and this leads to a decrease in the quality of the rolled surface, since the condition for optimizing the rolling force is violated. The radius of curvature of the roller rp with the known method of rolling in must be less than the smallest radius of the concave section of the part profile, which limits the allowable feed and thereby reduces the productivity of the process. The method of rolling around the envelope is that the point of contact of the roller (Fig. 1, b) with the part as it moves to position 1 'moves along the part in the process of mutual enveloping of their profiles. Thus, rolling in occurs both in the rolling plane – the cross section of the roller – and in the plane of supply of its axial section. The profile of the roller during rolling around the envelope [1, 8] can generally have variable curvature, consistent with the curvature of the part so that at each point the optimal conditions for their contact are ensured. In particular, with this method, the same reduced curvature of the profiles (R_{np} - const) can be provided, which allows the use of a constant working force, sufficiently large feeds and guarantees the surface quality and high productivity of the process. In addition, rolling around the envelope allows you to more evenly load the working surface of the rollers due to the gradual displacement of their contact point with the part along the axial section profile, and the displacement is also provided when rolling parts with a straight line generatrix, for example, the profile of the groove of a V-belt pulley.

The value of this fact is especially great for increasing the resistance of small diameter rollers. The scheme of rolling around the conical surface with an end roller is shown in Fig. 1, c. The roller is fed by turning its axis in the plane of the axial section of the part. The shape of the roller – the radius of curvature of the profile, the position of the axis and the end of the roller relative to the center of curvature O – is determined based on the rolling mode, strength and placement of the roller in the cavity of the thread being rolled. The envelope angle necessary for the deformation of the annular coil along the entire height of its generatrix in the case of rounding without slipping [1, 9] is:

$$\varphi = \frac{h_p - \Delta - 2\left[r_p \sin\left(\alpha + \psi_{\max}\right) - x_o\right]\cos\psi_{\max}}{r_p \cos\alpha},$$

where Δ – is the guaranteed clearance between the roller and the part;

$\psi_{\max}$ – final contact angle of the roller with the part:

$$\psi_{\max} = \pi - \left[\alpha + \arccos\left(y_o \mid r_p\right)\right]. \tag{1}$$

In the process of enveloping, the diameter of the roller in contact with the coil changes. Its value is determined in connection with the coordinate angle ψ:

$$d_p = 2\left[r_p \sin\left(\alpha + \psi\right) - x_o\right] \tag{2}$$

and reaches a maximum at $\psi = 90^o - \alpha$; $d_{p\max} = 2\left(r_p - x_o\right)$. The radius of curvature of the roller in the section conducted normally to the coil generatrix is taken into account when determining the rolling force, assuming the estimated diameter of the roller:

$$d_p = 2\left[r_p - x_o / \sin\left(\psi + \alpha\right)\right]. \tag{3}$$

A device for running in the working surfaces of V-belt pulleys is shown in Fig. 2 [10].

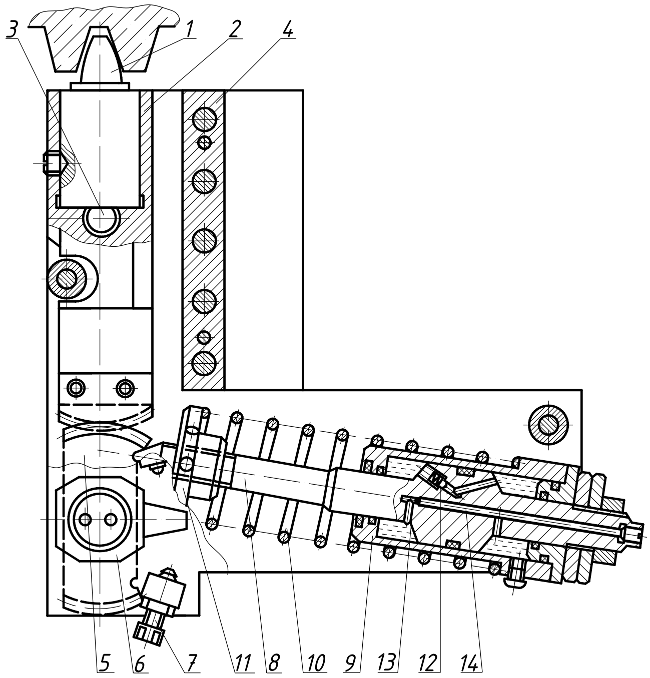

Fig. 2. Device for rolling rollers of V-belt pulleys

The cantilever roller 1 is installed in the bearing of the lever 2, which rotates on the axis 3 relative to the housing 4. The lower end of the lever 2 is connected via a gear 5 to the sector 5, to which the cam 6 is connected using a splined roller, the extreme position of the latter is determined by the stop screws 7. With one from the ends, sector 5 is pivotally connected to the piston 8 installed in the bore of cylinder 9. The force on the piston 8 is created by the spring 10 and is regulated by the nut 11. In the body of the piston 8 there is a valve 12 and a calibration hole 13, the cross-sectional area of which is adjustable It is driven by a locking rod 14. The device is installed in the tool holder of a lathe.

The device operates as follows [10].

The roller 1 is brought to the part being rolled in and pressed against it under the action of the spring 10 through the piston 8, sector 5 and lever 2. When the part is rotated, the device body 4 together with the machine support sets the feed movement along the part axis from right to left when rolling the right side of the stream, and from left to right - when rolling in the left side. Due to the rotation of the lever 2, the generatrix of the roller 1 goes around the profile of the part being rolled in, and the rolling is fed. When the lever 2 is rotated, the sector 5, which is engaged with the lever 2, rotates and, gradually compressing the spring 10, moves the piston 8 relative to the cylinder 9. The liquid poured into the cylinder 9 is poured through the valve 12 from right to left and allows the lever 2 to deviate freely during the rolling process, and when the roller 1 is withdrawn from the part, it prevents the quick return of the lever 2 to its original position. The lever 2 slowly rotates as the fluid flows from the left cavity to the right through the calibration hole 13.

To run around the left side of the stream profile, the piston 8 is transferred to the lower recess of the sector 4.

The feed Sc of the machine support when rolling the pulleys of the cone crushers is 1 mm / rev. details, which corresponds to a roll S of 2.1 mm / rev for the profile of the roller R = 160 mm. The run-in speed is 50 m / min. The optimal force on the roller, chosen in connection with the variable diameter of the roller with a material hardness of 140 HB changes in the process of enveloping the profile of the stream from 3 to 7 kN. The surface roughness before rolling corresponds to the parameter Rz = 20 μm, after rolling to the parameter Ra = 0.16 - 0.32 μm.

Conclusions

A device for rolling surfaces with a trapezoidal roller profile mounted on rolling bearings and pressurized to the detail by means of a lever power spring mechanism of loading, made in the form of a hydraulic actuator, the spring of which relative to the cylinder compresses the piston and pours the liquid through the valve, allows to uniformly and effectively deform the entire working surface, which leads to strengthening of the surface layer and reducing the surface and reducing the surface one pass and will increase the contact strength and durability of the workpiece.

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Марченко Д.Д., Матвеева Е.С. Повышение контактной прочности клиноременных шкивов с помощью пластического деформирования.

В статье приведены результаты исследования контактной прочности клиноременных шкивов при работе их на контактное смятие. Для повышения изностойкости и контактной прочности трибосопряжения предложен способ обкатывания роликом боковых поверхностей шкивов и устройство для его осуществления. Предложенный способ и устройство позволяют повысить износостойкость шкивов, а следовательно и долговечность в 1,6…2,1 раза.

Ключевые слова: контактная прочность, пластическое деформирование, упрочнение, износостойкость, клиноременной шкив, шероховатость.