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Research into the technology of rolling-in of rotating parts for agricultural machinery

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Through theoretical and experimental studies of the technology of rolling-in of rotating parts with rollers, it has been shown that, taking into account the rigidity of the machine tool-tool-part system and the stabilization of rolling-in forces, it was possible to achieve optimal rolling-in modes and, as a result, expand the range of rolling-in machine parts.

Undulation on the surface even when the hardening rolling possible to exclude a decrease in friction roller bearings site by replacing the sliding bearings for rolling bearing.

For the reinforcement of metal products rolling large machines, when a high degree of plastic deformation is necessary and significant depth of penetration, the most widely used spherical or toroidal roller, and at high angles of pressing roller φ_a in the direction of feed run-in surface details appear wavy with a pitch perfect the value of feed.

The main reason for the appearance of undulations, many researchers [1-2] consider the presence of mechanical runout roller, resulting in variable supply rolling. To prevent waviness in finishing rolling recommend taking a corner indentation φa value of 2-3o (which, however, limits the roughness of the surface run-size of 40<Rz<160 microns), and to reduce the ripple to use the commercials with the exact profile of the workers and often their to regrind. When the hardening rolling thin surface layer to prevent surface waviness to grind or grind it significantly reduced the effectiveness of work hardening.

We have proposed a method of eliminating the waviness on the surface of the run-in with the stabilization efforts rolling cyclically changing with each turn of the roller of the variables in the direction of the efforts of friction in the bearings mounting arm with a roller in the housing run-in tool [2]. Effort to stabilize rolling replacement sliding bearings that are mounted lever bearings. More than an order of decreasing friction force in the fulcrum of the lever, which leads to stabilization efforts in the run-in roller.

In Fig. 1 shows the calculation of step with nonrepeating waves Sw respects D_d / D_p, where D_d – diameter of a trial run of the details, D_p – the diameter of the roller. The dots on the net roller track rolling on his part noted the place of maximum effort R. The points, moving along the surface of parts, form a helix with a pitch S_w, superior to *S*. Along these lines, the deformation of the metal parts of the surface layer gets more than in the intervals between them, which causes the appearance of waviness.

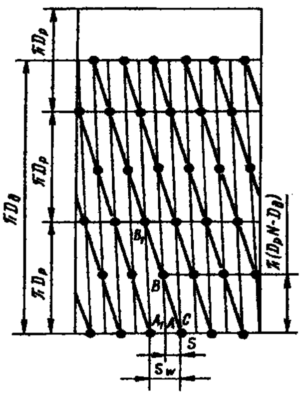
From the similarity of triangles *ABC* and $A_1V_1S_1$ that step wave

$$S_w = \frac{D_p S}{D_p N - D_\partial}, \qquad N = \left[\frac{D_\partial}{D_P}\right] + 1, \tag{1}$$

where the *S* – supply, *[Dd / Dp]* – the integer part of the relationship.

Equation (1) is valid for the case excluding slip clip on the details in their relative rotation, sliding in the presence of actual wavelength step may differ significantly from the calculated one. Rotation axis of the roller around the perpendicular to the contact surface in one direction or another can change the degree of slip roller, and thus affect the value of S_w.

Stabilizing by installing roller unit for rolling bearings rolling force *P*, we can eliminate the appearance of waviness at high angles of indentation, which are characteristic of the hardening even rolling. At the same time manage to get the surface roughness of *Ra* =0,08-0,32 *m* in the original *Rz* = 80-160 *m*, in addition, to combine finishing and hardening rolling.



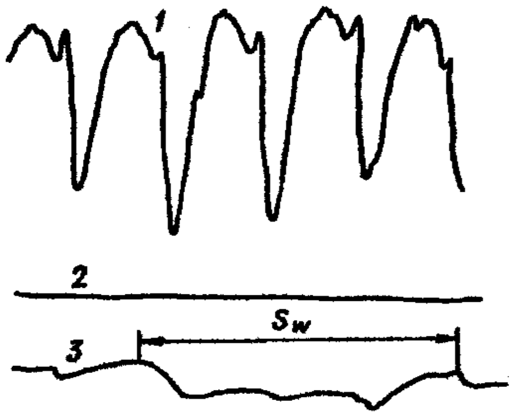


Fig. 1. Scheme for calculating the step wave rollers:1 - to rolling (Rz = 100 microns);2 - after installing roller rolling site on ball bearings (Ra = 0,08-0,16 m), 3 - after installing roller rolling site on the plain bearings (Rz = 16 mm)

Fig. 2. Profilograms surface of the shaft: t rolling

Stabilizing by installing roller unit for rolling bearings rolling force P, we can eliminate the appearance of waviness at high angles of indentation, which are characteristic of the hardening even rolling. At the same time manage to get the surface roughness of R_a = 0,08-0,32 m in the original R_z = 80-160 m, in addition, to combine finishing and hardening rolling.

Presented in *Fig*. 2 profilograms surface of the shaft of the most mild-steel 20, *HB* 140 and after rolling with normal effort *Pun* = 5 *kN*, *S* = 0,2 *mm* / rev details, D_d = 117 mm, D_p = 60 *mm*, show the effectiveness of the installation site on the roller ball bearings. The curve 3 shows the incipient ripple on the surface of the run-in with a step of S_w = 3,9 *mm*, which corresponds to S_w, calculated by the formula (1).

Rolling efficiency can be enhanced also by the use of rolls of small diameter (barrel-shaped and cylindrical), which completely eliminates the appearance of waviness and sliding the roller unit in the device due to the smallness of the angle φa.

At the same time constant effort rolling during processing can ensure the availability of data on the stiffness of the technological system machine-tool-item. In terms of preserving the optimal regime is a danger rolling not only reduce the stiffness, as its volatility.

The implementation of the optimal regime rolling associated with the capabilities of the machines. One of the conditions in this case is the ability to create and stabilize the work effort required value. In unilateral scheme rolling versatile devices one rollers effort rolling fully perceived the nodes of the machine, so it is limited in size and features proprietary tools. The constancy of the required effort is directly related to the rigidity of the technological system machine - tool - a detail. Rigidity of the system consisting of several units is determined by the AP Sokolovsky.

$$\frac{1}{j} = \frac{1}{j_1} + \frac{1}{j_2} + \frac{1}{j_3} + \ldots \tag{2}$$

One of the main components of the stiffness - the stiffness of the machine. In terms of preserving the optimal regime is a danger rolling less stiffness reduction as its volatility. For example, if rolling on lathes end of the shaft, but the rigidity of the caliper, the rigidity of the system significantly affects the rigidity front and rear pasterns. It is considered that as the slide movement of the headstock to the rear of the stiffness is reduced by 40-60%. According to the St. Petersburg Technical University in lathes with high 200-300 mm centers differential hardness of 50-100%, reaching in some cases four times. A similar pattern is observed in large lathes with center height of 500-1500 mm.

Obviously the change in hardness during processing on the boring and boring machines. By increasing the spindle off 3 times the rigidity of spindle assembly with a boring machine spindle diameter 90 mm drops 4 times a machine with a spindle diameter 150 mm - 3.5-fold [3]. In typical rolling rollers distribution of effort increases the hysteresis curve of the force - depressed. This is due to the determining role of joints in deformation units of machine tools [4]. The elastic deformation of their constituent parts are a fraction of the deformation nodes. In *Fig*. 3 shows the experimental dependence of the deformation of the radial force for three lathes of different sizes [1]. At the beginning of unloading force drops sharply under very small displacements associated with elastic deformation of the parts without the involvement of the joints. At this point, the stiffness of the system is very high, it is measured in hundreds of kilonewtons per millimeter.

In the process of securing parts rolling eccentric, radical heartbeat clips and other errors cause the system that works in the vibrational mode of unloading - loading near the maximum applied load. Simulation of the process by six successive cycles of load changes within the 8.5-10.5 *kN*, made on a lathe with a center height 286 *mm*, is represented by a curve on an enlarged scale in *Fig. 3*. The resulting graph shows that the rigidity of the system remains in the region of very high values, typical for unloading branch of the curve $P = f(y)$. The problem of stabilization efforts rolling within the allowable tolerances is solved by introducing into the design flow forming device of the elastic elements of low stiffness.

Combining the expression (2) the rigidity of the machine, parts, mounting accessories and a common symbol highlighting the rigidity of the tool obkatyvaniya, we find that the stiffness of the system [1]:

$$j = \frac{j_c j_u}{j_c + j_u}\,. \tag{3}$$

Let us suppose that the ratio of stiffness to the stiffness of the tool of other elements, then

$$j_u = m j_c\,. \tag{4}$$

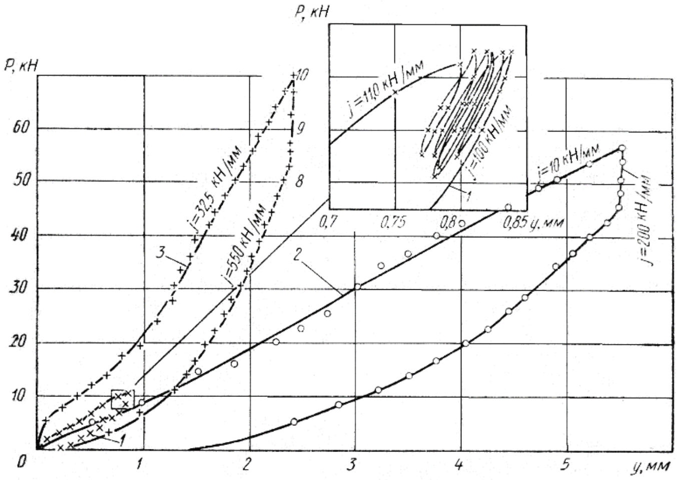


Fig. 3. The dependence of the spin lathe carriage from the radial force at the height of centers: 1 - 286 mm, 2 - 500 mm, 3 - 1250 mm

If the stiffness in the range from to, $j_{c\ \max} = nj_{c\ \min}$ and then an introduction to the technological system tools with hardness of formula (4) would reduce these fluctuations:

$$\Delta j = j_{\max} - j_{\min} = \frac{m}{1+m}(n-1)\,j_{c\min}\,.$$

The oscillations decrease in the rigidity of the system time, $\frac{1+m}{m}$ or $\frac{100}{m}\%$ at.

One of the ways to stabilize the radical rolling rollers is an exception to the overall stiffness of the technological system of the transverse stiffness of the machine. In the production of widely used Multi-Idler rollers rolling covering different types of devices. A rolling holes of great length would have been impossible without the use of Multi-Idler heads with a balanced radial pressure. When rolling sheeting or thin-walled parts of the stiffness must be taken into account.

Consider the strength of a system tool - detail by the example of rolling sleeves. We represent the bush in the process of rolling out a thin cylindrical shell simply supported at the ends and loaded in the middle section of the radial components of the effort, evenly spaced around the circumference and attached at the points of contact of the rollers. This case was considered in P.P. Beylarda [5]. Differential equations are solved by the expansion shell displacements and stresses in the double Fourier series. As a result, we obtain an expression for the radial displacement, which is suitable for numerical calculations:

$$\omega = \frac{12Rl^3(1-\mu^2)P}{\pi h^3 E\rho}\Big[\sum_{n}^{\infty}(-1)^{\frac{n-1}{2}}\frac{\sin\frac{n\pi}{l}x}{n^4\pi^4+12(1+\mu^2)\alpha^4\gamma^2}+$$

$$+\sum_{m}^{\infty}\sum_{n}^{\infty}(-1)^{\frac{n-1}{2}}\frac{2(m^2\alpha^2+n^2\pi^2)^2}{T}\cos(Rm)\varphi\sin\frac{n\pi}{l}x\Big],$$

where P – radial force on each clip; R – the number of reels; E, μ – the elastic modulus and Poisson's ratio of the material roll out sleeves; $\rho = \frac{|D_Д|}{2}; l; h$ – radius, length and thickness of the wall sleeve; $\alpha = \frac{2l}{|D_Д|}; \gamma = \frac{|D_Д|}{2h}$; x, φ – cylindrical coordinates;

$$T = (m^2\alpha^2 + n^2\pi^2) + 12(1-\mu^2)n^4\pi^4\alpha^4\gamma^2 - m^2\alpha^4\left[2m^4\alpha^4 + (6+\mu-\mu^2)n^4\pi^4 + (7+\mu)m^2\alpha^2n^2\pi^2\right]$$

The calculations were performed on a computer for the cylinder diameter $|D_Д|$ = 300 mm with different ratios of radius to wall thickness $\gamma = \frac{|D_Д|}{2h}$ and length to the radius $\alpha = \frac{2l}{|D_Д|}$.

The decision taken in the calculation of the shell hinged ends with infinite stiffness in the radial direction can not serve as a model for real-mount bushings near the ends of the sheeting. From the results of the calculation of practical importance are the deflections at a sufficient distance from the ends of the shell for large values of α.

For loading sleeve is made a special hydraulic load cell (*Fig.* 4), which has eight radially arranged working cylinder and the cylinder load imposed on the opposite end of the central mandrel. The mandrel is installed in bearings Centrists with a cone for attaching the dynamometer in the tailstock quill lathe.

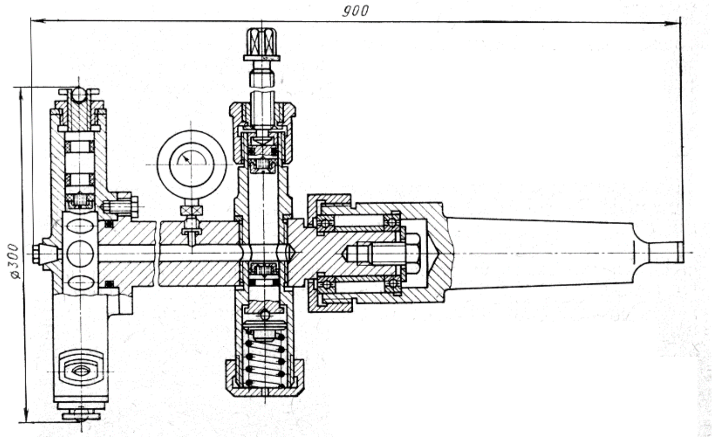


Fig. 4. The dynamometer load for radial bushings efforts

Needed to stabilize the work force reduction rolling rigidity of the system is achieved by using technological tools with spring elements.

In *Fig.* 5 shows a device with a springy one rollers housing for rolling shaft. An important advantage of this type of instruments lies in their simplicity. The required reduction in stiffness is achieved by changing only the configuration of the body without adding additional details. Resilient body is a cantilever, a circular beam of rectangular cross section. His deflection at the axis of the roller can be calculated based on the efforts rolling P and the geometric.

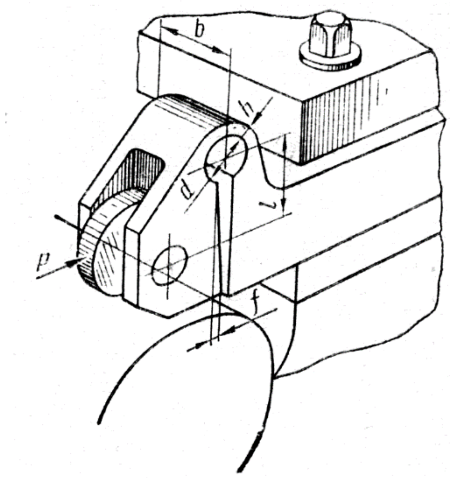


Fig. 5. Universal one rollers device with springy body

dimensions *b, h, d, l (Fig.* 4):

$$f = \frac{12}{E}\cdot\frac{P}{b}\left[\frac{\pi}{16}\left(\frac{d}{h}+1\right)^3+\frac{l}{h}\left(\frac{d}{h}+1\right)^2+\frac{\pi}{2}\left(\frac{l}{h}\right)^2\cdot\left(\frac{d}{h}+1\right)\right], \qquad (5)$$

where *E* - modulus of elasticity of the material.

The deflection of the force per unit width of the springy part of the body is determined by its relative size. Cases of similar shape in longitudinal section, and of equal width at equal deflections give the same effort. However, deflection, and hence the allowable load is limited elasticity of the case:

$$\frac{P}{b} < \frac{\sigma_T h}{1+\dfrac{\left(2\dfrac{l}{h}+\dfrac{d}{h}+1\right)\left(1-k\dfrac{d}{h}-k\right)}{k\dfrac{d}{h}\left(\dfrac{d}{h}+1\right)}}, \qquad (6)$$

where $\sigma_т$ - the yield stress of the material body; k - coefficient determining the position of the neutral layer of the circular bar, depending on the $\frac{d}{h}$.

We write:

$$c_f = \frac{12}{E}\left[\frac{\pi}{16}\left(\frac{d}{h}+1\right)^3+\frac{l}{h}\left(\frac{d}{h}+1\right)^2+\frac{\pi}{2}\left(\frac{l}{h}\right)^2\left(\frac{d}{h}+1\right)\right]; \; c_p = \frac{1}{1+\dfrac{\left(2\dfrac{l}{h}+\dfrac{d}{h}+1\right)\left(1-k\dfrac{d}{h}-k\right)}{k\dfrac{d}{h}\left(\dfrac{d}{h}+1\right)}}.$$

Then $$f = c_f\frac{P}{b}; \quad \frac{P}{b} < c_P\sigma_T h. \qquad (7)$$

Studies of the rigidity of the technological system machine tool-tool-part were carried out. According to the dependencies of the theory of elasticity, the rigidity of thin-walled bushings was calculated depending on the number of rollers in the rolling device, the rigidity of the elastic element of the rolling device was calculated, the results of the calculations are presented in the form of graphs, according to which it is possible to select the permissible rolling force when using devices with different geometric dimensions of the elastic element.

A technology and a device for rolling non-rigid shafts with a spring element of the housing were developed, a device with stabilization of the rolling force by replacing the sliding supports in it with rolling supports, which made it possible to ensure uniform deformation of the metal of the surface layer and combine finishing and strengthening treatment of the surfaces of parts operating under conditions of wear and contact crushing. A device for rolling non-rigid bushings with flexible rollers was developed. A patent of Ukraine was obtained for the developed device.

List of sources used:

1. Zubiekhina-Khaiiat O. V. Modeling the process of rolling threads and worms with rollers. *Bulletin of Agricultural Science of the Black Sea Region.* 2017. Вип. 4. С. 194-201. URL: https://dspace.mnau.edu.ua/jspui/handle/123456789/3408.

2. Marchenko D. D., Zubiekhina-Khaiiat O. V. Research on the stiffness of the machine tool-tool-part system during the repair of parts using the method of surface plastic deformation. Bulletin of the Petro Vasylenko Kharkiv National Technical University of Agriculture. 2018. № 192. Machine reliability problems. С. 99–109. URL: https://dspace.mnau.edu.ua/jspui/handle/123456789/5318

3.Research and development of technology for strengthening rope blocks by rolling them with rollers / O. V. Duha, D. D. Marchenko, B. O. Artyukh and other. *Eastern European Journal of Advanced Technologies*. 2018. Т. 2. № 1 (92). С. 1-11. URL: https://dspace.mnau.edu.ua/jspui/handle/123456789/3171

4. Zubiekhina-Khaiiat A. V. Mathematical modeling of the process of rolling body rolls with needed rollers. *Problems of tribology*. 2019. Vol. 93, no. 3. P. 45–50. URL: https://doi.org/10.31891/2079-1372-2019-93-3-45-50.

5. Пат. 54685 Україна, МПК6 B24B 39/00. Device for impact finishing rolling of holes / B.I. Butakov, V. O. Artyukh, O. V. Zubiekhina. № u201003962 ; заявл. 06.04.2010 ; опубл. 25.11.2010. Бюл. №22. URL:https://sis.nipo.gov.ua/uk/search/detail/255082/