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TECHNOLOGICAL PROCESS OF FORMING MICRORELIEF BY MECHANICAL PROCESSING ON THE SURFACES OF PRINTING EQUIPMENT PARTS

The article presents a proposed comprehensive technological process (CTP) for mechanical processing of flat guide parts of printing equipment (PE). The results of processing flat guides by grinding and surface plastic deformation (SPD) with the formation of regular microrelief (RM) on their surfaces are given. The modes of mechanical grinding and surface plastic deformation are determined. An analytical dependence between the relative bearing area of the microrelief and the processing modes has been established. Characteristics of the microrelief as well as the results of improving surface quality parameters and performance properties are presented.

Keywords: surface plastic deformation; grinding; microrelief; processing modes; quality parameters; wear resistance; performance properties.

Introduction

The reliability and durability of machine parts and mechanisms of printing equipment depend on the quality of the surface and surface layer. The causes of damage and destruction of structural elements during operation are processes occurring on the surface and in the subsurface layer: microcrack formation, scuffing, scoring, local wear, redistribution of residual stresses, weakening, etc.

To address these issues, machine designs are improved, higher-quality materials are used, and new technological processes are developed especially those with strengthening effects.

The selection, development, and implementation of strengthening technological processes allow for significant improvement of surface quality parameters and, consequently, performance characteristics of products (wear resistance, joint strength, corrosion resistance).

To improve surface quality and, therefore, the performance of metal products, methods of SPD, thermal, cryogenic, physical, physicochemical, and chemical-thermal strengthening are applied.

In this regard, we have proposed one of the most effective technological processes for improving surface and subsurface layer quality and, consequently, the operational properties of parts and mechanisms of printing equipment: vibration burnishing of flat surfaces. This process replaces imperfect, labor-intensive manual operations such as scraping and lapping, which traditionally enhance frictional performance oil retention, smooth motion, prevention of jamming and seizing, noiseless operation, corrosion resistance, and reduced labor intensity.

An analysis of literature and patent sources, as well as manufacturer data, showed that the issue of vibration burnishing of flat surfaces has not been fully explored.

Studies [1–3] proposed forming partially regular (PRMR) and fully regular (FRMR) microreliefs of sinusoidal and ring types, as well as rectangular and hexagonal patterns, on cylindrical surfaces after mechanical processing.

Research [4–7] investigated the formation of regular microreliefs on cylindrical surfaces followed by chromium plating to increase wear and corrosion resistance and improve printing equipment performance.

Studies [8–10] focused on forming regular microreliefs on printing equipment parts used in manufacturing integral book covers, followed by surface modification through ion nitriding in a helicon discharge plasma — while maintaining the microgeometry unchanged after the final operation.

Methods

The aim of the work is to develop a comprehensive finishing-strengthening technological process to increase wear resistance of flat guide parts of printing equipment operating under friction, based on the analysis of existing technologies for forming regular microreliefs. The study also seeks to determine the influence of processing modes on surface quality and wear resistance.

The SPD process was performed on a vertical milling machine using a specially designed vibration device (Fig. 1). The device is mounted with a bracket *3* on the quill *2* of the milling machine *1*. A spring *4* generates a defined pressing force through deforming tools *6* onto the surface of the part *7*. The preload is adjusted with a nut *5*. The part is fixed in a special fixture on the machine table *8*. Reciprocating (oscillating) motion is transmitted from the machine spindle *11* through an eccentric *9* and connecting rod *10*.

The treated area size is determined by the eccentricity (2e). The pressing force is adjusted by the calibrated spring. The deforming tools used were balls made of bearing steel ШХ15 (HRC 61–64). During processing, the part is mounted in a fixture that is secured on the machine table.

Results

A comprehensive technological process for processing steel 20X (HRC 43–46) was developed, consisting of three stages:

At the first stage of the comprehensive technological process (CTP), the flat surface of the part is ground. The arithmetic mean deviation of the surface profile after grinding is Ra = 0.14–0.12 μm.

At the second stage of the CTP, a partially regular sinusoidal microrelief (PRMR) is formed on the ground surface. The vibration burnishing parameters are as follows:

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pressing force on the surface of the part P_1 = 280 N, radius of the deforming tool sphere R = 3 mm, number of deforming tools K = 4, eccentricity of the deforming tool e = 14 mm, longitudinal feed rate of the milling machine table with the workpiece V = 250 mm/min, spindle rotation speed N = 63 rpm.

The geometric parameters of the microrelief after the second processing stage are: depth h = 0.0056 mm, width b = 0.38 mm, ridge height hn = 0.003 mm, and cross-sectional area of the microrelief F = = 0.0012 mm^2.

At the third stage of the CTP, the pressing force and the longitudinal feed rate of the deforming tools are reduced, while the spindle rotation speed and, consequently, the number of oscillations of the deforming tools increases. After processing, sinusoidal grooves remain on the surface to retain lubricant, with areas between them exhibiting enhanced geometrical and physicomechanical characteristics.

The vibration burnishing parameters at the third stage of the CTP are: P_2 = 220 N, R = 3 mm, K = = 2, e = 14 mm, v = 25 mm/min, N = 300 rpm.

Geometric parameters of the microrelief after the third stage of the CTP: h = 0.0025 mm, b = 0.2 mm, hn = 0.0012 μm, F = 0.0005 mm^2.

The most informative parameter that determines the operational properties of machine parts and mechanisms with microrelief is the relative bearing area of the microrelief.

We propose to calculate this parameter as follows:

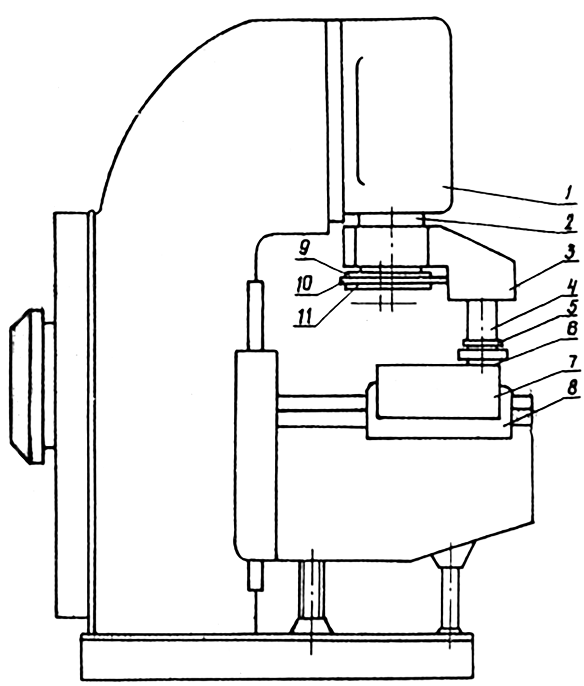

Fig. 1. Vibration device for forming microrelief on flat guide parts

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$$Fm=\frac{K\times\sqrt{\left(P_1-P_2\right)\left(2R^2\pi\times HRC-P_1-P_2\right)\times\times\left(V^2+16N^2-e^2\right)}}{\pi\times HRC\times R\times V\times e}\times 100\,\%. \qquad (1)$$

Statistical analysis of literature and online sources shows that the value of F_m for parts operating under friction conditions ranges between 25 % and 35 %. The established analytical relationship between F_m and the processing parameters makes it possible to determine the required vibration burnishing modes.

Discussion

The proposed technological process improves the physico-mechanical characteristics of the subsurface layer of the processed metal. The surface microhardness increased to H_m = 5560 MPa compared to the initial microhardness of H_m = 4400 MPa.

In addition, this technology causes a change in the ratio of martensite to retained austenite. The surface of the samples strengthened after grinding contained 5–9 % of retained austenite.

To enable prediction of the wear resistance of parts processed by the proposed technology, experiments were conducted according to a D-optimal design matrix (plan B3).

The wear resistance of vibration-burnished samples was compared with that of ground samples using a wear testing device. Samples with microrelief and ground surfaces were fixed on the table of a vertical milling machine. The weight of the test samples was less than 0.2 kg. The moving sample, made of cast iron, was mounted in the upper part of the wear testing device. The load on the friction pair was applied by compressing a calibrated spring. Lubricant was supplied to the friction zone through a dropper system.

The amount of wear was determined by comparing the weight loss of the samples, with the measurement error not exceeding ±0.15 mg.

As a result of the experimental plan implementation, a second-order mathematical model was obtained. This model for the comprehensive technological process grinding and vibration burnishing for obtaining partially regular (PRMR) and fully regular (FRMR) microreliefs has the following form:

$$Узн = 5{,}5 - 0{,}23P - 0{,}4R - 0{,}005P\times R + 0{,}088\times R^2 + 0{,}006\,P^2.$$

$$5{,}4 - 0{,}22P - 0{,}37R - 0{,}006P\times R + 0{,}09\times R^2 + 0{,}007\times P^2. \qquad (2)$$

This equation (2) allows predicting the wear of flat guide parts depending on processing modes. A graphical representation is shown in Fig. 2.

Conclusions

The developed comprehensive technological process (CTP) significantly improves the surface quality and performance properties of printing equipment parts.

The proposed analytical relationship enables determination of optimal CTP parameters. On sinusoidal microrelief areas, surface microhardness increases by 24–26 % compared to the original state. Between sinusoidal grooves, geometrical and mechanical parameters are improved.

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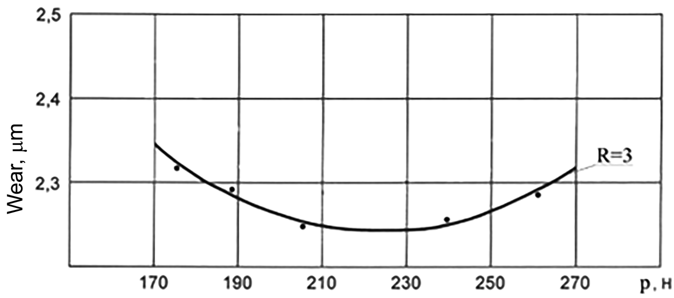

Fig. 2. Graphical dependence of part wear on pressing force and tool radius

The conducted research demonstrates that wear resistance increases by a factor of 3.3 compared to ground surfaces.

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У статті представлено комплексний технологічний процес (КТП) механічної обробки плоских напрямних деталей друкарського обладнання (ДО). Наведено результати обробки плоских напрямних шліфуванням та поверхнево-пластичною деформацією (ППД) з формуванням регулярного мікрорельєфу (РМ) на їх поверхнях. Визначено режими механічного шліфування та ППД. Представлено характеристики мікрорельєфу, а також результати покращення параметрів якості поверхні та експлуатаційних властивостей.

Ключові слова: поверхнева пластична деформація; шліфування; мікрорельєф; режими обробки; параметри якості; зносостійкість; експлуатаційні властивості.

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