Technological Support Of Surface Layer Of Optical Metalware

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Abstract. In the article the justification of the parameters of the polishing regimes in the processing of surfaces of parts with the purpose of smoothing their surface layer. The procedure was developed calculating the time of the whole process of processing parts made of copper and aluminum, the time of each transition and the grain size of the abrasive at each transition. The paper considers the issues of technological support for smoothing the surface layer of optical metal products under conditions of abrasive polishing. A significant effect of processing time on the surface roughness parameters has been established. Proceeding from this, it was proposed that abrasive polishing be carried out in several technological transitions, reducing the granularity of the abrasive at each transition, up to a grain size of 1/0. The minimum number of transitions of the technological cycle is established to obtain the minimum values of the height parameters of surface roughness.It is shown that the stabilization time of the formation of the altitude parameter of surface roughness depends little on the granularity of the abrasive, and is determined by the initial surface roughness before processing. A technique has been developed for calculating the time of the entire process of processing parts made of copper and aluminum to obtain a mirror surface, the number of transitions, the time of each transition and the grain size of the abrasive at each transition. The results of the work can be used for abrasive polishing of surfaces of laser mirrors with high reflectivity and surfaces of parts operating under conditions of light exposure in outer space.

Keywords: Abrasive Polishing, Roughness Parameters, Granularity Abrasive, Copper, Aluminum, Processing Time.

1 Introduction

Reduced labor input and production costs and the improvement of their quality is the most important task. Numerous studies have established that the decisive role in providing the state of the surface layer plays the active characteristics, which finally is formed at the finish operations. This is especially true for metal products that work under conditions of light exposure and lose their performance due to the appearance of temperature deformations. The creation of optical surfaces on these metal products makes it possible to reduce the temperature of their heating, temperature deformations and, accordingly, to increase operational characteristics. One of the effective solutions in this direction is the creation of optical surfaces of metal products by reducing their roughness during mechanical and physical-technical processing. The greatest effect is achieved in the process of abrasive polishing. However, at present, issues related to the possibility of a significant reduction in surface roughness during abrasive polishing and ensuring the required optical properties of metal products have not been sufficiently studied. Therefore, the urgent task is to determine the rational conditions of abrasive polishing, providing the required surface roughness.

2 Literature Review

The work [1, 2] is devoted to the problem of improving the operational characteristics of parts by technological methods, where the main scientific points are formulated. The regularities of the formation of surfaces of parts, taking into account their optical properties during abrasive polishing, are disclosed in [3–7]. They focus on the issue of choosing rational technological environments (abrasive grains, their grain size and concentration). In [4, 8], the features of magnetically abrasive polishing are disclosed, which provide higher technological parameters of the machined surfaces than with conventional abrasive polishing. The conditions [1, 2, 9] are devoted to determining the conditions for achieving the minimum surface roughness during abrasive treatment and, accordingly, abrasive polishing. In these works, the authors associate a change in the optical properties of surfaces with a change in the nature of the nonmetallic film, and do not consider the effect of roughness. In [10 – 14], attention is drawn to the need to smooth the surface layer of a part during abrasive polishing to increase reflectivity. In the works [1, 2] it was shown that the efficiency and productivity of abrasive polishing depends on the technological environment, which includes a polishing pad, an abrasive and non-abrasive component of the technological composition and the material of the workpiece. At the same time, traditional approaches [1, 2], having a developed apparatus, do not allow explicitly taking into account the specific features of the dynamics of the polishing process with respect to grinding [15 – 17]. All this reduces the effectiveness of technological decisions and makes them unsuitable in practice. In the proposed recommendations for the use of abrasive materials for polishing, there is insufficient information on the processing time necessary to achieve the greatest smoothing of the surface layer. Therefore, the objective of the study is to develop recommendations for reducing polishing time to achieve a given smoothing of the surface layer.

3 Research Methodology

Abrasion polishing, depending on the nature of the abrasive media used and technological fluids is a mechanochemical smoothing process surface layer by plastic deformation of microroughness, removal of oxides from the surface being treated. The polishing process is followed by successive application to the surface processed parts of a large number of scratches and traces of plastic deformation when they overlap and intersect. The technological liquid ensures the removal of wear products (metal particles and abrasive particles) from the surface of the processed details, helps to cool the surface layer of the workpiece.

The intensity of processing depends on the dynamic parameters determined by the polishing modes, the duration of polishing, the characteristics and dimensions of the abrasive particles, and the characteristics of the mechanical properties of the material of the part.

The cutting tool is formed directly during processing as abrasive an environment with special properties and certain internal connections. The complex geometric shape of the grains and their cutting parts is one of the most important characteristics abrasive tools.

The abrasive tool will first contact the projections of the initial roughness of the surface, with gradual rounding of the protrusions. In the polishing process, the height parameters of the profile of the initial roughness of the surface will decrease, and the step parameters will change insignificantly. If the polishing process is stopped after 30 seconds from the start of polishing, then at the initial roughness after grinding a part of the initial microrelief will remain, while the roughness of the surface of the part will consist of smoothed protrusions.

The reference surface of the machined part at levels of 10, 20, 30, 40 % will be significantly increased in comparison with the original, and the basins of the microrelief will remain unchanged. Continuation of the polishing process will lead to the complete removal of the protrusions of the initial roughness. Ratio of altitude parameters R_a / R_{max} will decrease in this case. This indicates the occurrence of a large number of scratches on the polished surface, associated with the presence of an enlarged fraction in commercially available abrasive powders. In the future, the polishing process is stabilized. The relief characteristic for the polishing process will be constantly reproduced, its parameters will not change over time, but will be determined by processing modes and graininess applied abrasive.Based on this, experimental studies of the parameters of surface roughness, material removal rate should be carried out and the minimum number of transitions of the technological cycle to establish the minimum values of the height parameters of surface roughness should be established. This will allow a scientifically sound approach to the selection of optimal conditions for abrasive polishing.

4 Results Of The Work

We studied the influence of abrasive graininess and the duration of preliminary treatment on the values of the height parameters of the surface roughness for samples from steel 30ХГСА (fig. 1). From the graph (fig. 2) it can be seen that the intensity of the change R_{max} does not correspond to the rate of change of values R_a. With increasing grain size, the abrasive value R_{max} are increasing.

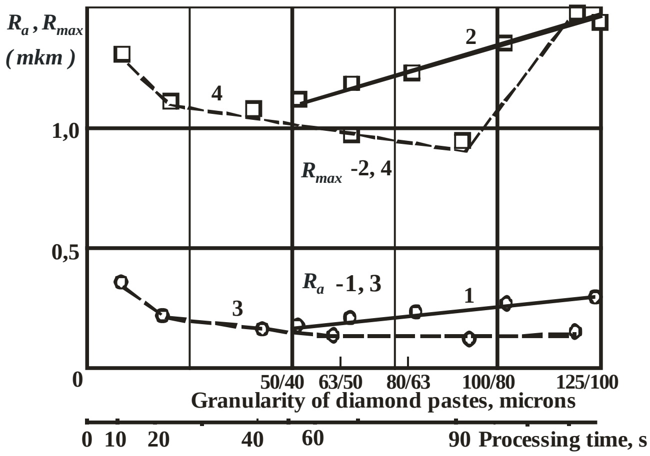

Fig. 1. Effect of graininess of diamond pastes 1, 2 and treatment time 3 and 4 on the intensity of change in the values of the altitude parameters of the roughness, surfaces for samples from steel 30ХГСА:pressure 40 MPa; Circumferential speed30 m/s; time of processing 20 seconds for 1 and 2; Granularity of abrasive for 3 and4 - graininess 50/40

With increasing processing time, the intensity of the change R_{max} sharply increases that can be explained by crushing the grains during processing, hence the processing process it is necessary to stop before the intensive destruction of grains. As with the reduction in the grain size (with the force of pressing the polishing pad unchanged), the contact pressure increases and, accordingly, the depth of scratching by a single crushed grain should be greater, R_{max} increases while preserving the smoothing effect. Ascending contact pressure contributes to the simultaneous collision of many abrasive grains, increasing the energy of motion of crushed grain. From the graph we see that the ratio R_a / R_{max} in the initial period of polishing to 90 seconds decreases slightly, and with an increase in processing time above 90 seconds the value of this ratio decreases and is 0.087. This reduces the quality of the processed surface. The value of the ratio of the altitude parameters depending on the graininess of the abrasive tape varies slightly, but when polishing with diamond paste small granularity 2/1, the values of this ratio are sharply reduced. Therefore, it is necessary to establish optimal values for the processing time and grain size of the abrasive, based on the requirements for surface roughness.

To solve this problem, we use the paper [1], which gives the dependence of the removal rate Q on the parameters of the polishing process:

$$Q = k \cdot V^{a} \cdot c^{b_1} \cdot e^{b_2 c} \cdot p^{d_1} \cdot e^{d_2 p}, \qquad (1)$$

where V – is the cutting speed, m/s; P - pressure, kPa; c – is the density of the abrasive slurry, G/ml; K, a, b, d are the coefficients.

We have obtained dependencies characterizing the change in the removal of the material from the part from one variable for fixed values of two variables.

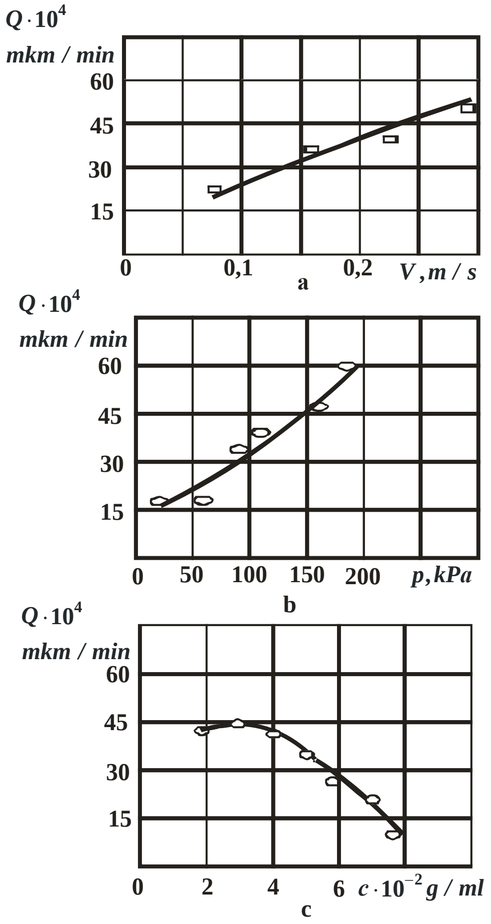

Fig. 2. Dependence of the removal rate Q on the parameters of the abrasive process: the linear velocity V (a); pressure p (b); is the density of the suspension c (c)

Cutting speed with changing cutting speed:

$$Q(V) = 2{,}39 \cdot 10^{-2} \cdot V^{1{,}15} \quad (\text{with } c = 2 \cdot 10^{-2}\, g/ml; p = 12 \cdot 10^2 kPa).$$

Rate of removal when pressure changes:

$$Q(p) = 0{,}68 \cdot 10^4 \cdot p^{-3{,}38} \cdot e^{0{,}0173p} \quad (\text{with } V = 0{,}2\ m/s; p = 12 \cdot 10^2\ kPa). \qquad (2)$$

The rate of removal when the concentration of abrasive suspension is changed:

$$Q(c)=1{,}14\cdot 10^{8}\cdot c^{5{,}64}\cdot e^{1{,}46c}\ \text{(with } V=0{,}2\ m/s;\ p=12\cdot 10^{2}\ kPa)\,.$$

In fig. 2 shows the experimental and calculated points obtained by the formulas (2). The discrepancy between the calculated and experimental values of material removal no more than 3 %. To smooth the surface layer of the parts, a minimum тumber of technological cycle transitions to obtain minimum values poneycomb parameters of surface roughness. At the end of the first processing cycle, we get surface, the roughness of which R_1, and the altitude parameter of the initial liability R_0. When performing$N$ cycles, we obtain N surfaces with intermediate values of high-altitude roughness parameters R_i in accordance with different transition. The number of transitions and the intermediate value of the surface roughness depends on the physicochemical properties of the surface to be treated, its shape, processing time, properties and graininess of abrasive material.

In abrasive polishing, we believe that the maximum depth of grain penetration is equal to the diameter of the abrasive particle or its maximum size. In this case, the height parameters of the surface roughness and the material removal rate at each transition are proportional to the dimensions of the abrasive particles:

$$R_{z_i}=\beta\cdot D_i\,;\qquad Q_i=\alpha\cdot D_i\,, \tag{3}$$

where D_i – diameter of abrasive particles at the *i*-th junction (*i* = 1, 2 ... *N*-1); α and β – Coefficient the proportionality factors, determined empirically, are constant for this processing process.

It follows from (3) that

$$Q=\frac{\alpha}{\beta}\cdot R_{z_i}\,. \tag{4}$$

In table. 1 shows the values of the rate of polishing and roughness during processing for one hour parts from copper by various fractions of diamond micropowders.

Table 1. Results of abrasive polishing

Surface roughness after milling R_1, mkm	The diamond-micropowders, graininess	Spee Polishing $Q\cdot 10^3$ mkm/min	Roughness after polishing, R_z , mkm
0,32	5/3	5,325	0,032
0,32	3/2	3,225	0,050
0,32	1/0	1,35	0,020

The size of the allowance *h*, corresponding to the depth of the defective layer, has the form: $h_i = k \cdot R_{z_{i+1}}$,where k is the coefficient of proportionality, which determines the amount of material removed in time t_1

$$t_i = \frac{F_i}{Q_i} = \gamma \cdot \frac{R_{z_{i-1}}}{R_{z_i}} , \tag{5}$$

where $\gamma = \dfrac{k\beta}{\alpha}$ with $i = 1, 2, \ldots, N$.

The total processing time for all cycles is:

$$T_i = \sum_{i=1}^{N} t_i = \gamma \cdot \sum_{i=1}^{N} \frac{R_{z_{i-1}}}{R_{z_i}} . \tag{6}$$

To optimize the process by the minimum criterion, the total processing time (5) it is necessary to determine the optimum values of the intermediate surface roughness R_{z_i} , $i = 1,\ 2,\ ...,\ N-1$: $R_{z_i} = R_{z_{i-1}} = R_{z_{i+1}}$, whence $\dfrac{R_{z_{i-1}}}{R_{z_i}} = \dfrac{R_{z_i}}{R_{z_{i+1}}}$.

Taking formula (6) into account, it follows from Eq. (5) that under the optimal process, the transition time is the same, i.e. $t_1 = t$. This is true for surface treatment details with the same value of the height parameters of the roughness of the initial surface. However, this is not confirmed for samples with different initial surface roughness, since with decreasing initial roughness of the surface, the processing time sharply decreases. This is confirmed by the results of the experiment (fig. 3).

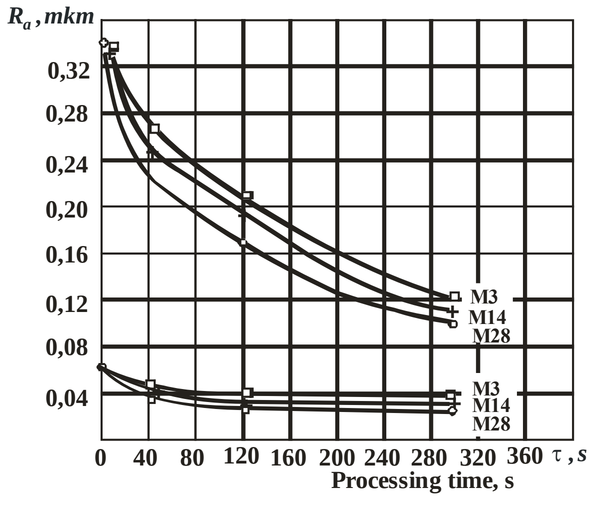

Fig. 3. Dependence of the height parameter of the surface roughness on the time no polishing with abrasive materials of different granularity

Dependency analysis shows that:

- time of stabilization of the process of formation of the altitude parameter of roughness the surface depends little on the grain size of the abrasive (from M3 to M28);

- time of stabilization of the process of formation of the altitude parameter of roughness surface significantly decreases with a decrease in the height parameter of the initial roughness of the surface before processing. When the initial roughness parameter of the surface is decreased R_a in 5.23 times (from 34 microns to 0,065 microns), the stabilization time R_a the treated surface is reduced 8 times (from 320 seconds to 40 seconds).

Thus, with smoothing, the top layer of the part, the cycle time of the subsequent finish operation will decrease more intensively than the reduction of the initial roughness parameter before processing;

- for each grain of abrasive material, there is a limit on stabilization values of the altitude parameter of the surface roughness, and this is very important when assigning a sequence of use of working media for smoothing the surface layer details. It should be noted that this limit will depend on the initial state of the surface of the part before processing. We are interested in the smallest limiting value R_a, achieved by surface polishing under different processing conditions.

The optimal values of the total processing time can be determined from the following expression: $T = \gamma \cdot N \cdot (\frac{R_{z_0}}{R_{z_N}})^{1/N}$. The optimal number of cycles is obtained by considering the total time T as a function of number of cycles N. Define its minimum: $N_{min} = ln\frac{R_{z_0}}{R_{z_N}^{1/N}}$.

The optimum value of diameters of abrasive particles at each transition is:

$$D_i = \frac{1}{\beta} \cdot \frac{R_{z_N}^{1/N}}{R_{z_0}^{1/(N-1)}} = \frac{1}{\beta} \cdot R_{z_0} \cdot \left(\frac{R_{z_N}}{R_0} \right)^{1/N} \quad \text{at} \quad i = 1,\ 2,\ ...,\ N .$$

Carrying out similar calculations for the cases of surface treatment with changing physical and chemical properties, the expressions will take the form:

$$T_{opt} = \gamma \cdot N \cdot \left(x \cdot \frac{R_{z_0}}{R_{z_N}} \right) 1/N \text{ at } N = 2{,}3 \cdot ln \left(x \cdot \frac{R_{z_0}}{R_{z_N}} \right).$$

From the foregoing it can be seen that the coefficients x and γ reflect the dependence of the polishing rate on the microhardness, the density of the material being processed and the grain size diamond micropowder. It was experimentally established that for diamond micropowders of the corresponding granularity the value x is 0.06, γ is 1.7.

Consequently, the optimal variant of the polishing process from the point of view of minimum transitions when processing a metallic mirror surface is determined only by the roughness height surface before and after treatment. It should be noted that the minimum number of transitions depends on the physical and chemical properties of the abrasive, the initial roughness of the surface $R_{z_0} = D_0 \cdot \beta$, Granularity of diamond micropowders $D_N = \beta \cdot R_{z_N}$ used at the last transition. The developed technique was used to optimize the polishing process of a copper mirror surface [18]. For the initial state, samples were taken with the surface treated to $R_a = 0{,}5$ mkm,at the final stage of processing, the roughness was $R_z = 0.032 \ldots 0.025$ mkm. Then the optimal number of cycles is 3, and the time (averaged for the upper and lower limits) is $T = 7.87$ min. Studies have shown that the estimated time from the experimental difference is 20 % (T_{econ} = 9.5 min), which corresponds to an error $\varepsilon = 0.01$. For abrasive compounds, the grain sizes at the respective stages processing: $D_1 = 3.1214 \ldots 5$ mkm; $D_2 = 1.1543 \ldots 2.05$ mkm; $D_3 = 0.425 \ldots 0.8$ mkm which corresponds to granularity of abrasives 5/3; 3/2; 1/0.

5 Conclusions

1. In work theoretically and experimentally revealed patterns the formation of surface roughness when polishing with abrasive materials of various grain sizes of copper and aluminum parts. It has been established that the ratio of surface roughness parameters R_a / R_{max} with an increase in the processing time significantly decreases (to a value of 0.087) and reduces the quality of the surface being treated. This is due to the crushing of abrasive grains. Therefore, for the effective implementation of the process of abrasive polishing, it is necessary to establish the values of the processing time based on the requirements for surface roughness.

2. The rationale for the optimal parameters of the polishing modes during surface treatment of parts with the aim of smoothing their surface layer and ensuring optical properties is given. The minimum number of transitions of the technological cycle is established to obtain the minimum values of the height parameters of surface roughness. The grit of the abrasive in this case must be reduced at each transition.

3. Based on the studies carried out, a the procedure for calculating the time of the entire processing process, the number of transitions, the time of each transition and the grain size of the abrasive at each transition.

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