TECHNOLOGY OF CREATING OF OPTICALLY FUNCTIONAL SURFACES ON METALWARE

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Abstract: The article provides the justification of the parameters of the polishing regimes when machining surfaces of parts made of copper and aluminum in order to smooth their surface layer. It has been established that the technological support of the surface of laser mirrors with high reflectivity ρ_λ at a wavelength of 10.6 microns, the surface of parts with low absorptivity A_s in the wavelength range from 0.2 to 2.5 microns is associated, first of all, Values of the contact potential difference (CPD). The ratio of the height parameters of the surface roughness R_a / R_{max} can be used to control the surface defects after applying the finishing methods of processing. Smoothing of the surface layer should be carried out step by step, reducing the grain size of the abrasive. After grinding, it is necessary to perform abrasive polishing with diamond paste ACM 5/3 for 1 minute. After thorough cleaning of the surface from the residuals of the working medium, the treatment with diamond paste ACM 2/1 should be applied for 1 minute and at the final stage the treatment should be carried out with a suspension of nanopowder Al_2O_3.

Keywords: polishing, laser mirror, reflectivity, surface roughness, finishing machining methods, grain size of abrasive.

Introduction

The development of scientific research related to the provision of the required parameters of the macro and microgeometry of the surface, the state of the surface layer of products with optical properties of surfaces, is currently receiving increasing attention. Improving the processing quality of optical metal products is an important scientific and technical task [1-3].

The mechanism of cutting during the finishing processes is described in the work of Kedrov S.M. [4]. In his opinion, when processing surfaces with putty rubbing with an abrasive mixture, the grains that are between the lapping and the surface to be treated are embedded in both surfaces simultaneously. Depending on the shape and size of the grains, relative movement of the surfaces may lead to rolling or shearing of grains. This leads to scratching or squeezing out the pits on both surfaces. In softer materials, the process of seeding grain is more intense.

The influence of a viscous liquid in the composition of an abrasive mixture by Kedrov S.M. reduces to the shift of abrasive grains from the surface of the lapping and to the hydrodynamic effect due to the creation of oil wedges of various thicknesses. In this case, the weighted state of the abrasive particles will depend on the viscosity of the liquid.

Grebenshchikov I.V. [5] proposed a theoretical model of polishing. When the hardness of the abrasive is below the hardness of the film of oxides formed under the influence of atmospheric oxygen, then the metal is only removed from the surface to be treated as this film. If the surface to be treated is connected to the anode, the rate of film formation will increase, and the associated chemical processes will have a positive effect on the effect of the polishing process.

As can be seen from the results of the studies given in [6], the contact potential difference can be achieved by abrasive treatment (polishing, finishing), blade processing (turning using superhard materials, including natural diamonds), surface-plastic deformation [7].

In addition to the machining methods, electrochemical or chemical polishing can be used to provide high reflectivity, which, due to the specific nature of the process, create surface layers with a favorable fine structure and provide the maximum values of the contact potential difference (CPD). The surface roughness criterion is used to estimate roughnesses on the surface F [8, 9].

By definition, the roughness criterion for a surface F [10]. The relationship between the surface roughness criterion F and the optical characteristics (absorption coefficients A_{sm} (smooth surface) and rough surface radiation ε_r) can be described using the well-known formula [8]:

$$\varepsilon_r = \frac{\varepsilon_{sm}}{1-(1-A_r)\cdot(1-F)}, \qquad (1)$$

where ε_r - coefficient of radiation of a rough surface; ε_{sm} - coefficient of radiation of a smooth surface; A_{sm} - absorption coefficient of a smooth surface.

At present, traditional methods for obtaining high reflectivity of laser mirrors from various materials (copper, aluminum and its alloys, molybdenum, etc.) find cutting machining, both blade-cutting with cutters made from natural diamonds, and treatment with free abrasives - polishing (finishing) Using resin polishers and process media containing diamond micropowders [11].

The purpose of the work is to develop recommendations for ensuring the quality of the surface of optical metal products.

Analytical research

In [6], the analytical dependence of the ratio of the height parameters of the roughness R_a / R_{max} on the relative length of the roughness profile l_0 and the angle at the apex of the abrasive grain γ was obtained in the following form:

$$\frac{R_a}{R_{max}} = \frac{1-\frac{1}{l_0}}{1-sin\gamma}\cdot\left[1-0{,}5\cdot\frac{1-\frac{1}{l_0}}{1-sin\gamma}\right], \qquad (2)$$

where l_0 – the relative length of the profile of roughness; R_a - average arithmetic deviation of the roughness profile; R_{max} – the maximum value of the altitude parameter of the roughness; γ - half the angle at the top of the abrasive grain.

The relationship between the surface roughness criterion F and the ratio of the surface roughness parameters R_a / R_{max} has the following form [6]:

$$F \approx 1-\frac{R_a}{R_{max}}. \qquad (3)$$

It follows from these dependencies that the optical characteristics of the surfaces are determined not simply by the roughness parameters R_a / R_{max}, but by their ratio R_a / R_{max}, which can vary over a fairly wide range: 0 ... 0.29. This indicates the possibility of a significant improvement in the optical characteristics of the treated surfaces and, accordingly, the performance characteristics of the critical parts, considering the relative profile length l_0 and the ratio of the arithmetic mean deviation of the profile to the maximum value of the surface roughness parameter (R_a / R_{max}) as a criterion for estimating the roughness. As shown above, the surface roughness criteria l_0, R_a / R_{max} and F are analytically related. Thus, as the R_a / R_{max} decreases, the roughness criterion F increases, and l0 decreases. Accordingly, the emission factors ε_r and absorption A_r of the treated surface are reduced, and the coefficient of reflection of light ρ_r increases. From the point of view of the geometry of the surface, in order to increase its reflectivity, it is necessary to reduce the ratio R_a / R_{max} (due to the removal of traces of abrasive grains) and the relative profile length l_0, while the surface roughness criterion F will increase.

To determine the influence of technological polishing factors on the variation of the height parameters of the surface roughness, we construct the dependences of Fig. 1 and Fig. 2.

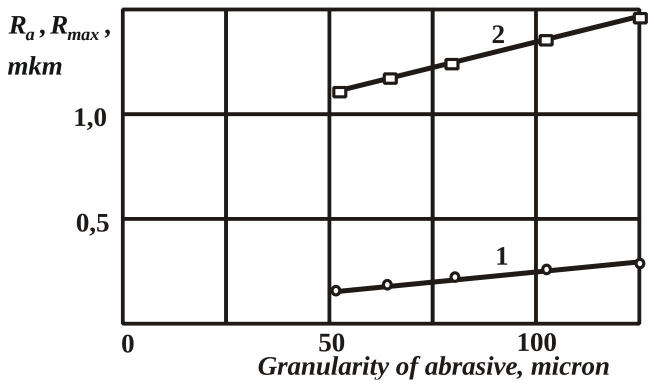

Fig. 1 – Effect of abrasive grain on the intensity of changes in the values of the height parameters of the surface roughness of a sample made of steel 30ХГСА: processing conditions: pressure 40 MPa; cutting speed 35 m / min; processing time 20 s;
1 – R_a ; 2 – R_{max}; before processing R_a =0,68 microns, R_{max} = 3,64 microns

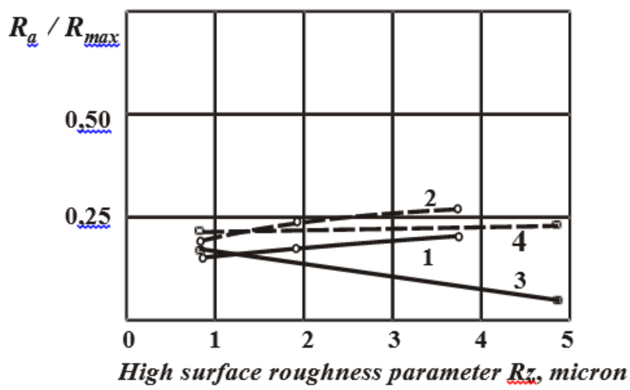

Fig. 2 – Effect of abrasive treatment on the height parameters of the surface roughness: sample material: 1, 2 – steel 30ХГСА; 3, 4 - titanium alloy VT4, processing mode: pressure 40 MPa; cutting speed 35 m/s; processing time 20 s; granularity of abrasive ACO 50/40; 2, 4 - before processing; 1, 3 - after treatment

From the graph (Fig. 1) it is seen that the intensity of the change R_{max} does not correspond to the intensity of the change in values R_a. As the grain size of the abrasive decreases R_{max} the values change insignificantly with respect to the corresponding one R_a. At the same time, increasing the grain size of the abrasive for the same initial surface (before processing) increases the value of the ratio R_a / R_{max} (after treatment).

When processing different samples with different initial roughness of surfaces with increasing values of the height parameters of the roughness before processing, the value of the ratio R_a / R_{max} decreases (for equal granularity of the abrasive, pressure and processing time).

Analysis of the dependencies (Fig. 1 and Fig. 2) makes it possible to justify the choice of grain size of the abrasive for the stages of polishing the surfaces of the parts [12, 13]. The grain size of the abrasive must correspond to the value of the high-altitude parameters of the surface roughness before processing.

The following sequence of cycles of technology of surface treatment with small values of parameters of roughness is offered. The first treatment cycle is carried out with diamond micropowders with a grain size of 5/3, using a polyvinyl alcohol surfactant as a surfactant, which increases the rate of removal of the material to the amount of removal, as in the case of using a larger grain size abrasive, and this reduces the duration of the processing cycle. The second cycle should be carried out using diamond micropowders with grain size 2/1 with similar processing conditions as in the first cycle. On the third cycle of processing it is recommended to use nanopowders Al_2O_3, with processing conditions of the first and third cycles.

We have studied the mechanism of the formation of a surface with high reflectivity by machining on mirrors made of copper and aluminum alloys [11].

The change in parameters and optical characteristics of surfaces after natural diamond turning and diamond polishing, which had the maximum values of the roughness criterion of the surface.

After diamond turning of mirrors from an aluminum alloy AMZ, the reflectance (at a laser radiation wavelength λ=10,6 microns) had a value of 96.6%, and after diamond polishing - 92.6 %.

The value of the absorption coefficient was 0.1 and 0.20, respectively.

The favorable combination of physical and chemical properties of natural diamond and processed surfaces, the decrease in the intensity of the action of chemically active substances, leads to a decrease in the reflectivity of surfaces treated with diamond tools, which leads to a decrease in the various kinds of inhomogeneities in the double electrical layer of the surface and reduces the work function of the electrons. On the surface of the aluminum sample, the contact potential difference (CPD) value is 1050-1100 mV, and after polishing using diamond micropowders – about 880-900 mV.This disadvantage of abrasive processing is manifested as a result of the influence of currently used abrasive compounds on the physico-chemical properties of the metal surface being treated, associated with oxidation processes. This is explained by the fact that with this type of treatment free electrons lead to oxidation of the surface layer. The thickness of the resulting oxide film is, as a rule, much larger than the height of the irregularities on the real metal surface.

In abrasive polishing, the surface to be treated adsorbs, reactive substances contained in the process phases and air oxygen, which affects the development of chemical-mechanical phenomena accompanying the plastic deformation of microprotrusions of the surface. The adsorption process is intensified by the mechanical removal of oxide films from the surface, which is provided by a relative change in the contact of the polishing pad and the surface to be treated.

When comparing the images of surfaces of samples from the AMg3 alloy after diamond cutting and abrasive polishing, significant differences were found. On polished surfaces, in addition to traces of abrasive grains, there are a large number of small "ripple" points that are absent on the surface treated by turning. The presence of "ripples", apparently, is the result of the interaction of organic components of polishing compounds, abrasive grains and the surface to be treated. On the surface treated by turning, traces of a cutter with a depth of 0.1-0.2 microns and a width of 60 microns can be observed, the slopes are smooth, almost unevennesses commensurate with the wavelengths of the incident radiation.

Significant differences in the state of the surfaces after turning and polishing are confirmed by X-ray diffraction studies.

After abrasive polishing, the surface is deformed to a lesser degree than after diamond turning. However, the chemical activity of aluminum in air, the non-abrasive components of the working medium, as well as the caricature of the surface with an abrasive form a substructure in the form of a conglomerate of metal oxides, fragments of abrasive grains, and alkali metal compounds.

Mass and Auger spectroscopy was used to determine heterogeneous substances and other impurities that do not belong to the main material, but formed during the surface treatment.

The results of such studies also confirm the significant differences in the composition of the surface layers after turning and polishing. It is established that in both cases the surfaces of the samples are covered with a complex film of chemical compounds whose composition depends on the method and processing conditions.

On the surface of the sample, treated with a diamond tool, mainly a film of aluminum and magnesium oxides of small thickness is formed. On the surface of the samples after polishing, a thicker chemical composition is formed than in the first case, in addition to aluminum and magnesium oxides, there are various compounds of bulk impurities in the sample material (alkali metals, their oxides, etc.).

The use of surface plastic deformation as well as diamond turning provides a surface with improved physicochemical parameters. However, limitations in the processing technology of this method make it possible to effectively apply it only on hard surfaces.

Table 1 shows some parameters of the surface layer of mirrors from copper Mob that were subjected to cutting, The data in the table show that blade processing leads to significant plastic deformation of the surface layers of the metal. As can be seen from the table, turning a hard alloy and diamond leads to a significant hardening of the surface to be treated.

Polishing with an abrasive slurry introduces significantly less changes into the structure of the surface layers, which are distributed in a surface layer of up to 60 microns thick when treated with diamond micropowder ACM 5/3. Subsequent polishing with diamond micropowder ACM 2/1 removes the level of structural distortions and reduces the depth of the deformed layer. A more uniform distribution of structural distortions of surface layers is formed by polishing fine-grained samples.

The decrease in the contact potential difference (CPD) value for diamond turning compared to abrasive polishing is due to the fact that the structure of the surface layer is distorted as a result of deformation, the presence of deformation is confirmed by X-ray structural analysis of the surface. The deterioration of the surface substructure during polishing leads to an increase in the work function of the electron.

To reduce the heterogeneity and the degree of structural distortion along the surface and the cross section of the samples, it is advisable to perform thermal treatment (annealing) after preliminary blade treatment. The modes of heat treatment should be selected so that when recrystallization in the surface layer a fine-grained structure is formed (grain size 10 microns).

In connection with the fact that caricaturing in the polishing process with diamond grains affects the physico-chemical state and thereby reduces the reflectivity, we investigated the character of the arrangement of the carried particles and the density of their distribution on the sample. As the metallographic analysis showed, the density of the carved particles from section to site varies in different ways (from 10^2 to 10^4 grains per 1 mm^2), no regularities in the distribution of the carried particles were found.

Table 1 – The parameters of the surface of the mirrors of copper Mob after the blade and abrasive treatments

Surface Parameters	Blade processing		Abrasive polishing with a suspension based on diamond micron powders ACM 2/1
	Turning the carbide tool	Diamond turning	
Depth of defective layer, μm	400 ± 50	300 ± 50	5 ± 7
The half-width of the diffraction line, $V{\cdot}10^4$ radians	168	160	10
Microhardness, Pa	1300 (P=0,99)	930 (P=0,99)	570 (P=0,98)
Criterion of roughness, F	0,95	I	I
Contact potential difference (CPD), mV	–	120	180
Reflectivity ρ_λ, %	95,9	99	99,2

Around the place of introduction of the diamond particle in the first stage of polishing, the material deforms more intensively, the density of the scales is several times larger in this region than the average on the surface. A surface layer analysis showed that the abrasive particles are distributed in it to a depth of up to 5 microns. The sizes of the implanted particles are 3 to 5 microns. At temperature exposure (temperature gradient over the cross section of the sample to 50 K/mm), the swirling surface undergoes swelling at the places of introduction of the carved particles.

Removing the surface layer with a thickness of 1-3 microns by electropolishing and subsequent polishing of the surface resulted in a decrease in the density of the carved particles of $10^2 \pm 10^3$ grains per 1 mm^2.

It was concluded in [14] that when the surface layer of a part is smoothed out, the cycle time of the subsequent polishing process will decrease more intensively than a decrease in the height parameters of the initial roughness before processing; For each granularity of the abrasive material, there is a limit to stabilizing the values of the altitude parameter of the surface roughness, and this is very important when assigning a sequence of use of working media when smoothing the surface layer of the parts. This limit will depend on the initial state of the surface of the part before processing.

Taking into account that the dependence of the height parameters of the surface roughness during polishing on the treatment time is stabilized by the first minute of treatment [6, 13], the smoothing of the surface layer should be carried out step by step, reducing the grain size of the abrasive. After grinding, it is necessary to perform abrasive polishing with diamond paste ACM 5/3 for 1 min. After thorough cleaning of the surface from the residues of the working medium, the treatment with diamond paste ACM 2/1 should be applied for 1 minute. And in the third step, the treatment is carried out with a suspension of nano powder.

Conclusions

It is developed the technological support for the surface of laser mirrors with high reflectivity ρ_λ at a wavelength of 10.6 microns, surfaces of parts with low absorptive capacity A_s in the wavelength range from 0.2 to 2.5 microns is associated, first of all, with maximum values Contact potential difference.

The ratio of the high-altitude parameters of the surface roughness R_a / R_{max} can be used to control surface defects after applying finishing methods of processing.

Smoothing of the surface layer should be carried out step by step, reducing the grain size of the abrasive.

The results of the studies should be used in the technological operations of finishing abrasive (abrasive polishing fine-grained diamond pastes) surfaces of laser mirrors with high reflectivity and surfaces of parts with low absorbency.

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