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JUSTIFICATION OF INCREASING THE DURABILITY AND PRODUCTIVITY OF PRECISION PARTS USING LASER METHOD

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ABSTRACT

The work summarizes and critically analyzes the existing criteria for optimizing the methods of increasing and restoring the surface hardness of precision parts of machines and devices, shows ways to improve and clarify them, and also attempts to select optimal methods for increasing and restoring the surface hardness of precision parts of machines and devices and develop a generalized model. Various methods for increasing and restoring the surface hardness of parts of machines and devices with increased surface hardness pose the most urgent problem of choosing the optimal option for specific production conditions from among various technological solutions. This necessitates a further study of methods for increasing and restoring surface hardness and is based on three criteria: applicability, durability and technical and economic efficiency. The solution to the problem of substantiating the optimal method for increasing and restoring the surface hardness of machines and devices should be carried out using properly selected optimization criteria, using controllable factors that have the greatest impact on the costs of the technological process.

1. Introduction

The activities of many enterprises show that enterprises are constantly looking for ways to remain competitive in market conditions. One of them is the continuous improvement of the level of organization of increasing the surface hardness of machines and devices using laser technology. To date, scientific research institutions have not developed and applied in production methods for increasing and restoring the surface hardness of precision parts of machines and devices. The importance of each of them should be determined by the goals and capabilities of the enterprise [1 - 4].

Various methods for increasing and restoring the surface hardness of parts of machines and devices with increased surface hardness pose the most urgent problem of choosing the optimal option for specific production conditions from a variety of technological solutions. It is necessary to ensure that the costs of increasing and restoring the surface hardness of precision parts are minimal. For this, it is necessary to take into account the maximum number of factors affecting the technology and organization of enterprises [5- 10].

The most acceptable forms of organization of increasing and restoring the surface hardness of parts: by defects, by route and by route-group. Depending on the program and type of production and repair work, it is necessary to choose one of the organizational forms (taking into account the type of production and repair enterprise) [11].

Defect technology is used in cases where the program for increasing and restoring the surface hardness of parts is small. In this case, the technological process is developed separately for each defect. Parts for increasing and restoring the surface hardness are processed only for parts of the same name, taking into account the combinations of defects in them.

Route technology is designed for complex defects that are eliminated in a certain sequence (route). In the design process, it is necessary to generalize the defects based on scientific and practical sources.

After the routes are determined, their number is determined (two or three), a rational method of eliminating defects is selected for each route, and a technological process scheme is developed for eliminating each defect. It is taken into account that when using defect technology, defects on the main surfaces are first eliminated, and then defects caused by thermal processing, deformation and other reasons are eliminated by taking into account mechanical processing [12].

Route-group technology involves the division of defective parts into classes and groups and the development of a single route technological process for increasing and restoring the surface hardness of groups of parts on one equipment using one tool.

Route and route-group technologies are used, as a rule, in manufacturing enterprises and repair plants.

In addition to meeting operational requirements, increasing the surface hardness of precessional parts of machines and devices (especially in market conditions) should be economically beneficial. In this regard, it is more expedient to use complex approaches and the interaction of multiple factors: constructive, technological, production, operational, etc. [13].

2. Materials and methods

Since in modern conditions the production of equipment has decreased by 20...30 times and the supply of spare parts has sharply decreased, the solution of the problem of increasing the performance of precessional parts of machines and devices is urgent. Therefore, the selection and justification of the method of increasing and restoring the surface hardness of precessional parts of machines and devices are the main tasks [14].

The analysis of scientific literature and research works showed that currently the assessment of methods of increasing and restoring the surface hardness of precessional parts of machines and devices is carried out according to the most generalized (technical and economic) criterion: $C_{SMA,Bi}$

$G_i = \frac{C_{SMA,Bi}}{K_{Di}} \rightarrow min;$ (1)

$G_i = \frac{C_{SMA,Bi} + E_H \cdot K_{YDi}}{K_{Di}} \rightarrow min,$ (2)

where,

$C_{SMA,Bi}$ – The unit cost of the defect elimination method using the ith method i, money/m^2;

K_{Di} - The durability coefficient of the part whose surface hardness has been increased and restored by the i-th method;

E_H - normative efficiency coefficient;

K_{YDi} - Special investment when eliminating the defect using the i-th method, money/m^2.

Choosing a rational method for increasing and restoring the surface hardness of parts. The methodology for selecting a rational method for increasing and restoring the surface hardness of parts is based on consideration of three criteria: applicability, durability, and technical and economic efficiency.

Application criterion or technological criterion

$K_m = f\,(M_d; F_d; D_d; Y_d; H_d; \sum_{i=1}^{m} T_i)$ (3)

where

M_d – is the material of the part;

F_d; D_d – The shape and diameter of the part with increased and restored surface hardness;

Y_d – wearing of the part;

H_d – The loading value and nature of the part where the surface hardness is increased and restored;

$\sum_{i=1}^{m} T_i$ – a set of technological characteristics of a method that determines its rational scope of application.

The application criterion allows you to determine the methods by which the surface hardness of parts can be increased and restored and is not expressed in numbers..

The durability criterion is numerically determined by the durability coefficient K_d, which is proportional to the service life of parts under operating conditions:

$K_d = K_Y K_B K_i$ (4)

where K_Y, K_B, K_i are the wear resistance, durability and adhesion coefficients of the coating, respectively. The most rational method can be selected based on the criterion of durability during operation.

$K_Y, K_B,$ coefficients are determined by wear and fatigue tests. The most commonly used method for determining K_i is the nail pull-out method.

The rational surface hardness increase and restoration method is a technological process that ensures the wear resistance and hardness of the part with increased surface hardness and restored surface hardness, providing a service life of at least 0.8 times that of the new part on the friction surface

3. Discussions

The optimal method for increasing and restoring the surface hardness of precessional parts of machines and devices is considered to be the method with the lowest value of the G_i criterion. Using formulas (1) and (2), it is advisable to determine the optimality criteria for individual parts. As a rule, manufacturing enterprises incur certain costs associated with increasing and restoring the surface hardness of a group (range) of parts, and in this regard, the optimal methods for one part may not always be optimal for a group of parts [5 – 9, 15].

Analysis of expressions (1) and (2) also shows that when evaluating methods for increasing and restoring surface hardness, it is assumed that the indicators $C_{SMA,B}$ and K_D are in equilibrium. However, taking into account the current trends in the production of machines and devices and the economy as a whole, the importance of these indicators is not equal. Determining the numerical value of the technical and economic criterion refers to calculating the costs of increasing and restoring the surface hardness of precessional parts of machines and devices and determining the durability coefficients.

The final decision on the feasibility of using the selected method is made in accordance with the technical and economic criterion, which is the correlation of the costs of increasing the surface hardness and restoring the part after eliminating defects with its durability [16].

The condition for the technical and economic efficiency of the surface hardness and restoration method is as follows:

$C_X \leq K_d\ C_H$ (5)

where C_X Costs of increasing and restoring the surface hardness of the part; C_H - is the cost of the new part.

The effectiveness of the surface hardening and restoration method is assessed taking into account the cost of environmental costs due to the characteristics of the physical and mechanical properties of the surfaces with increased and restored surface hardness. After increasing and restoring the surface hardness, the consumption of lubricants may decrease or increase, the time spent on maintenance may decrease or increase, and the service life of the connected part may decrease or increase. This criterion can be expressed by the following dependence [3, 4]:

$\sum C_{Э,в} \leq \sum C_Э$ (6)

where $\sum C_{Э,в}$ is the total operating costs incurred in the production or restoration service of a part with increased or restored surface hardness; $\sum C_Э$ - is the amount of operating costs incurred in servicing newly manufactured parts.

The economic feasibility of using this method to increase and restore the surface hardness of parts is assessed in the following sequence.

First, the cost of increasing and restoring the surface hardness of the part is determined:

$\sigma_{в,д} = \frac{\sum C_{в,д}}{L\ a}$ (7)

where $\sigma_{в,д}$ – The cost indicator for increasing and restoring the surface hardness of a part in a unit of value characterizing the operation of the machine (1 km of mileage between repairs, 1 hour between repair cycles); $\sum C_{в,д}$ – Costs of increasing and restoring the surface hardness of parts; L – Machine operating time between production and repair, km/h; a – The ratio of surface hardness to the performance characteristics of increased and restored parts, parts manufactured using factory technology [17].

Then, the cost indicator is determined in case of replacing the unusable part with a new one:

$$\sigma_{H,\partial} = \frac{\sum C_{H,\partial}}{L} \quad (8)$$

where $\sigma_{H,\partial}$ - Cost indicator when replacing a wearing part with a new one, per unit of value characterizing the overhaul period (1 km, 1 hour, etc.); $\sum C_{H,\partial}$ - is the value of the new part. In simplified form, the coefficient a is equal to one.

The ratio of cost indicators $\sigma_{в,\partial}$ to $\sigma_{H,\partial}$ characterizes the economic efficiency of increasing and restoring the surface hardness of wearing parts using the selected method:

$$\beta = \sigma_{в,\partial} / \sigma_{H,\partial} \leq 1 \quad (9)$$

where β is an indicator of the economic efficiency of increasing and restoring the surface hardness of the wearing part.

In the case of β ≤ 1, the method of increasing and restoring the surface hardness of parts is the most rational. It meets the requirements of the durability criterion, that is, it ensures high wear resistance and hardness of the part for at least 0.8 of the service life of the new machine, and also meets the requirements of the technical and economic criterion.

When β = 1, the method of increasing and restoring the surface hardness of parts meets the requirements of the durability criterion and does not lead to an increase in costs during repair and operation in the event of replacing a wearing part with a new one.

When choosing methods for increasing and restoring the surface hardness of precision parts of machines and devices, the cost is expressed by the following formula, depending on the annual program:

$$C_{SMA,B} = C_{\mathrm{Dy}} \bullet \mathrm{N} + C_{\mathrm{S}} \quad (10)$$

where,

$C_{SMA,B}$ – cost price;

C_{Dy} – part whose value varies depending on the program;

C_{S} – fixed part that does not depend on the program.

The advantage of this expression is that the author for the first time used an economically justified approach in the form of a technical and economic criterion to assess not only the costs of increasing and restoring the surface hardness of parts, but also the method of restoring precision parts of machines and devices. This correlates not only the costs of increasing and restoring the surface hardness of parts, but also the costs of preparing and machining precision parts after increasing and restoring the surface hardness [3, 4, 6 – 9, 11].

Unfortunately, when determining the costs of increasing and restoring the surface hardness of worn precision parts (plungers and dies) of machines and devices in this methodology, mainly current costs are visible, that is, the methodology is suitable for increasing and restoring the surface hardness of wearing parts only in specialized repair facilities of machines and devices [3, 4, 18].

Currently, when solving technical maintenance and service issues of machines and devices, the technical and economic criterion - permissible limit values of resource parameters (limitation of resource costs, etc.) using controlled factors is increasingly used, since this approach is even more important in a market economy.

Therefore, in order to justify the method of increasing and restoring optimal surface hardness, it is necessary to take into account the maximum number of factors affecting the total unit cost and the order of interaction of these factors with each other.

Thus, the solution to the problem of justifying the optimal method for increasing and restoring surface hardness of machines and devices - using controlled factors that have the greatest impact on the costs of the technological process, should be carried out using correctly selected optimization criteria

4. Conclusions

1. Currently, when increasing and restoring the surface hardness of precision parts, serious requirements are imposed on production and repair enterprises by the operator: economic, technological processes, working conditions, environmental safety and energy costs.

2. When optimizing the method of increasing and restoring the surface hardness of precision parts of machines and devices using laser technology, the characteristics of the factors affecting the process and the technological process are poorly correlated. In this regard, there is a need to create a generalized mathematical model for optimizing the technological process of increasing and restoring the surface hardness of precision parts of machines and devices using laser technology, taking into account reliability parameters, environmental safety and economic indicators.

3. When developing a mathematical model, it is more appropriate to evaluate the efficiency of the unit cost of the technological process and to select the optimal method for increasing and restoring the surface hardness of precision parts of engines, machines and apparatuses - to justify the objective function for laser technology.

4. Especially in cases of shortage of spare parts, wear of expensive parts, as well as increasing the wear resistance of the friction pair, a method of increasing and restoring surface hardness may be recommended.

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