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DETERMINATION OF FUNCTIONAL DEPENDENCES OF TECHNOLOGICAL MODES AND PARAMETERS IN INDUCTION SURFACE

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ABSTRACT

One of the practical ways to increase the wear resistance of products operating under various wear conditions: shock, shock-abrasive and abrasive - is the surfacing of the working parts that are most susceptible to this effect. The use of induction surfacing with the use of modern transistor generators makes it possible to form a given set of properties of the resulting composite material, which allows to significantly increase the resource of the product and, as a result, to increase the technical and economic indicators. High-energy impact makes it possible to control the rates of heating and cooling, which leads to the creation of maximum non-equilibrium structures, which, under certain conditions, can provide the required complex of physical, mechanical and operational properties. The control of the structure formation of materials of a given composition, under conditions far from thermodynamic equilibrium, makes it possible to provide the required durability of the working zone of the product, taking into account the nature of wear. The purpose of this work is to establish functional dependencies of technological modes and parameters for induction surfacing. In the course of the experimental studies, data were obtained characterizing the relationship between the following parameters - the deposition rate, the deposited layer thickness, the magnitude of the increase in wear resistance and the hardness of the material. The obtained functional dependencies between these parameters made it possible to determine the required deposition rate and the thickness of the deposited layer ensuring the formation of a given set of physical and mechanical properties of the composite material, taking into account the nature, which is of high practical importance.

Keywords: regression analysis, functional dependence wear resistance, induction surfacing, composite material.

INTRODUCTION

One of the practical ways to increase the wear resistance of products operating under various wear conditions: shock, shock-abrasive and abrasive - is the surfacing of the working parts that are most susceptible to such an effect. Controlling the structure formation of materials of a given composition, in conditions far from thermodynamic equilibrium, allows you to provide the required durability of the working area of the product, taking into account the nature of wear [3-9]. It is known that the use of induction technology makes it possible to control the processes of structure formation of the material, and, therefore, makes it possible to ensure the formation of a given set of physical and mechanical properties, depending on the nature of wear, using a weldable charge of the same composition [1, 2, 7, 10-15].

Therefore, the purpose of this work is to establish functional dependencies of technological modes and parameters during induction surfacing, ensuring the formation of a given set of properties, taking into account the nature of wear.

MATERIAL AND METHODS

Experimental studies of the obtained samples of composite material using a surfacing charge of the same composition [1, 2, 4, 5, 6, 16] made it possible to establish the relationship between the following parameters of induction surfacing - deposition rate, deposited layer thickness, increase in wear resistance and material hardness. The results of the studies are presented in Tables 1, 2 and 3.

Table-1. Dependence of the deposited layer thickness on the deposition rate, ensuring maximum wear resistance.

Surfacing speed, m/h	**6**	**6.1**	**6.3**	**6.5**	**6.7**	**7**	**7.5**	**8**	**8.2**	**8.5**
Deposited layer thickness, mm	4.5	4	3.5	3	2.5	2	1.5	1	0.7	0.5

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Table-2. Dependence of the increase in wear resistance on the thickness of the deposited layer in relation to the reference specimen of steel C60* at the optimum deposition rate.

Deposited layer thickness, mm	**0**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**
The amount of increase in wear resistance,%	0	18	27.6	36.7	44.6	52.2	58.4	63.2	68.2	71.8

* - Steel C60 contains 0.6% C, 1% Mn, the rest is iron.

Table-3. Dependence of material hardness on the thickness of the deposited layer at the optimum deposition rate.

Deposited layer thickness, mm	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.2**	**4.5**
Hardness, HRC	58	57	56	54	53	51	49	47	46	45

To determine the functional dependencies between these parameters, we will use the methods of regression analysis, during which the following designations are used:

x – deposition rate;
y – thickness of the deposited layer;
z – value of increase in wear resistance,
r – hardness.

The dependence of the deposited layer thickness on the deposition rate (function *y* (*x*)) will be determined using nonlinear regression. For this, we will interpret the values of the parameters presented in Table-1 as the values of random variables (*x*) and (*y*), which have some joint probability distribution (these values are denote dx_i and y_i, i=1…10).

Having analyzed the location of the points (x_i, y_i) in the coordinate system, we assume that the function y (*x*) has the following form:

$$y(x) = D_0 \cdot e^{D_1 \cdot x},$$

where D_0иD_1 - some regression parameters that we need to find. Let's find them in accordance with the principles of root-mean-square regression that is, using the method of least squares. As statistical estimates of the parameters D_0иD_1choose such values $\overline{D_0}$ и $\overline{D_1}$, which minimize the expression $\sum_{i=0}^{10}(y_i - y(x_i))^2$. We solve the problem of minimization using the Mathcad package, and as a result we find that the minimum of this expression is attained at values $\overline{D_0} = 500.102$ and $\overline{D_1} = -0.788$. To estimate the accuracy of constructing the regression, you can find an unbiased estimate of the standard deviationσ^2. It is calculated by the formula:

$$\overline{\sigma^2} = \frac{\sum_{i=1}^{n}(y_i - y(x_i))^2}{n-m},$$

where *m-1*–the number of unknown regression parameters (in our case*m-1=2*), and *n* – sample size (in our case *n=10*). We get that $\overline{\sigma^2} = 7.172 \cdot 10^{-3}$.

Consequently, the sought functional dependence *y* (*x*) has the form:

$$y(x) = 500.102 \cdot e^{-0.788 \cdot x} \quad (1)$$

Let's build a regression graph (Figure-1). The points on the graphs (Figures 1-3) show the data obtained as a result of the experiment, the solid line is the regression line that determines the functional dependence(*y(x)*, *z(y)*, *r(y)*).

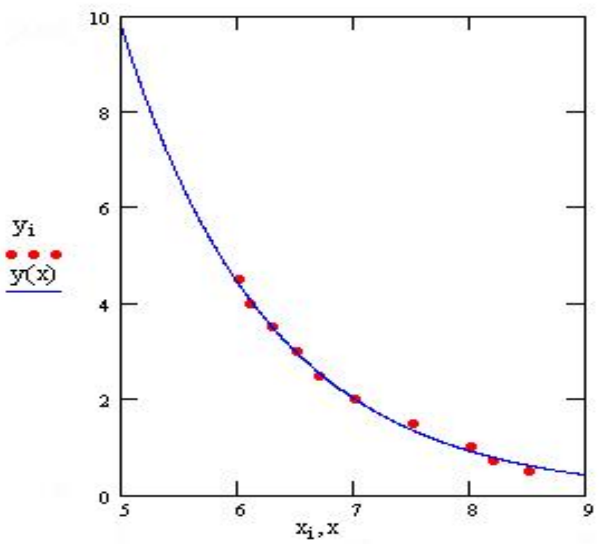

Figure-1. Dependence of the deposited layer thickness on the deposition rate for obtaining maximum wear resistance.

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Let us define the form of the inverse dependence x (y). To do this, let us logarithm both sides of expression (1). We get:

$$x(y) = -1.269 \ln y + 7.887 \qquad (2)$$

Let us carry out a similar procedure to determine the functional relationship between the deposited layer thickness y and the magnitude of the increase in wear resistance (z). We interpret the data from Table-2 as the values of two random variables that have some joint distribution. By plotting points with coordinates (y_i, z_i) on the plane, we assume that the dependence z (y) can be described using a logarithmic function:

$$z(y) = D_0 \ln(y + D_1) + D_2$$

In this case, we need to find statistical estimates of three regression parameters– $\overline{D_0}$, $\overline{D_1}$, $\overline{D_2}$. Using the least squares method, we obtain the following values: $\overline{D_0} = 47.114$, $\overline{D_1} = 1.263$, $\overline{D_2} = -10.415$.

Thus, the functional dependence x (y) takes the form:

$$z(y) = 47.114 \ln(y + 1.263) - 10.415 \qquad (3)$$

Let's build a regression graph (Figure-2).

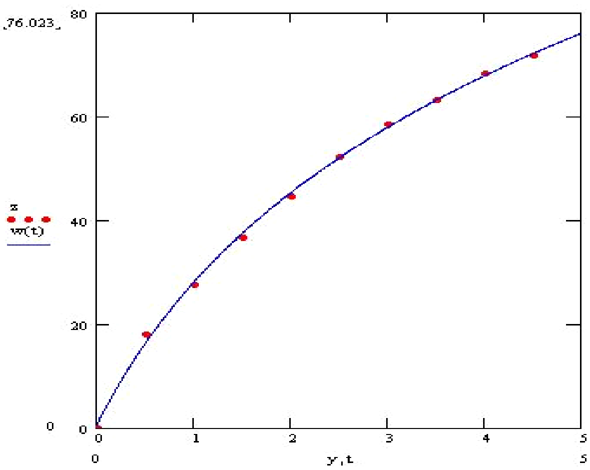

Figure-2. Dependence of wear resistance on the thickness of the deposited layer.

Unbiased standard deviation estimate:

$$\overline{\sigma^2} = 0.632$$

The inverse relationship is easier to deduce not analytically, as in the previous case, but also using regression. We get that:

$$y(z) = 1.267 e^{0.021z} - 1.282, \qquad (4)$$

wherein $\overline{\sigma^2} = 1.819 \cdot 10^{-3}$.

Let us determine the functional relationship between the thickness of the deposited layer (y) and the hardness of the material (r). Having built the points (y_i and r_i) on the coordinate plane, you can see that they are located practically on the same straight line, from which you can make an assumption about a linear relationship. We are looking for r (y) in the form:

$$r(y) = D_0 y + D_1$$

We get that $\overline{D_0} = -3.353$, $\overline{D_1} = 60.553$. The dependence of hardness on the thickness of the deposited layer has the form:

$$r(y) = -3.353y + 60.553 \qquad (5)$$

Let's build a regression graph (Figure-3):

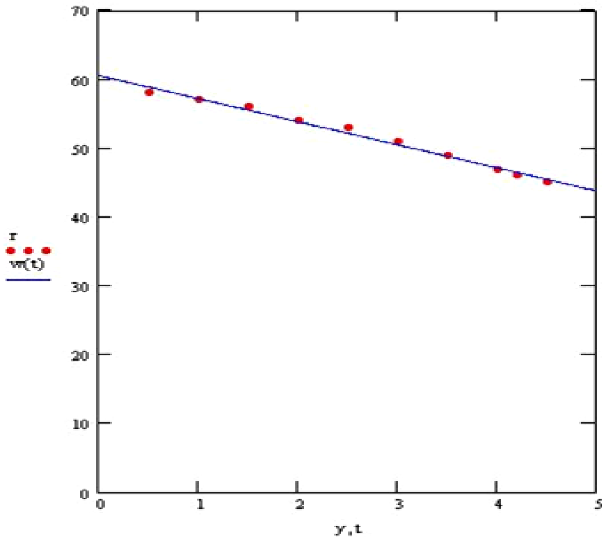

Figure-3. Dependence of hardness on the thickness of the deposited layer.

Unbiased standard deviation estimate:

$$\overline{\sigma^2} = 5.825 \cdot 10^{-3}$$

The resulting wear resistance can be calculated as:

$$Z = z_0 + z , \qquad (6)$$

where z_0 - wear resistance of the material under study before surfacing, z - is the increase in material wear resistance during surfacing.

Using the obtained functional dependences (1–5) and expression (6), we find y (Z) and x (Z). $y(Z)$ is determined directly from the dependence y (z), substituting

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for (z) the value Z-z_0. We get that knowing the required wear resistance; we can find the corresponding required deposition thickness by the formula:

$$y(Z) = 1.267e^{0.021(Z-z_0)} - 1.282 \tag{7}$$

In this case, the corresponding optimal deposition rate is calculated according to dependence (2). Substituting the expression from formula (2) into the resulting formula (7) instead of y and performing the necessary transformations (having logarithmized both parts of the obtained expression), we obtain the dependence x (Z). So, knowing the required wear resistance, we can find the corresponding required surfacing rate by the formula:

$$x(Z) = -1.269\ln(1.267e^{0.021(Z-z_0)} - 1.282) + 7.887 \tag{8}$$

CONCLUSIONS

The studies carried out made it possible to establish the relationship between the technological modes (deposition rate), the parameters of the deposited layer (thickness of the deposited layer), and the properties formed by the complex (hardness, wear resistance). Obtained functional dependencies$y(x) = 500.102 \cdot e^{-0.788 \cdot x}$,$z(y) = 47.114\ln(y + 1.263) - 10.415$, $r(y) = -3.353y + 60.553$, deposition thickness $y(z) = 1.267e^{0.021(Z-z_0)} - 1.282$ and the rate of obtaining a composite material $x(z) = -1.269\ln(1.267e^{0.021(Z-z_0)} - 1.282) + 7.8$, ensuring the formation of maximum wear resistance under specified operating conditions.

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