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BUILDING MATHEMATICAL MODEL FOR GAS-THERMAL PROCESS OF COATING EVAPORATION

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For mechanical engineering and other branches of industry the most progressive and economic technological processes permitting to increase wear resistance, corrosion resistance and other properties of the working surface of the produced machines are technological processes of gas-thermal coating evaporation. In the paper there is considered the scheme of gas-thermal coating evaporation and selected the optimum technological modes of gas-thermal evaporation. There is developed a mathematical model defining relations between the evaporation distance, the angle of the melted particles dispersion, the speed of the part rotation, the speed of the burner movement and the evaporated coating thickness.

Key words: coating, gas-thermal evaporation, mathematical model, dependence speed, thickness.

INTRODUCTION

At present the matters of essential increase of wear resistance of machine parts are mainly solved by introducing to the technology of their production the additional labor-consuming operations for hardening the part outer zone. An urgent task is searching for such strengthening processes which would combine the possibility of obtaining the surface roughness with high parameters and needed accuracy with simultaneous hardening of the outer zone. Gas-thermal technologies of evaporated coating strengthening meet these conditions [1].

At present in mechanical engineering there is a set of problems connected with the hydraulic equipment protection against corrosion impact [2].

In this connection gas-thermal coating evaporation on the elements of equipment gives a possibility to use materials without changing their properties.

The coatings can be multilayered that permits to use properties of various materials and to obtain coatings with the set properties including multipurpose or so-called pseudo-alloy coatings [3].

Pseudo-alloy coatings represent a separate type of composite coatings consisting of the materials which are not forming solid solutions and compounds in the liquid and solid state and differing in the melting temperature. The coatings obtained from materials like pseudo-alloys possess a number of properties: a combination of high values of melting temperature and evaporation to the mechanical durability, hardness, damping ability, wear resistance, ability to self-greasing in the conditions of dry friction, as well as high level electro- and heat conductivity [4].

The analysis of methods of pseudo-alloy coating evaporation showed that the most economic and simple is the gas-thermal evaporation.

In gas-thermal evaporation it is needed to take a set of factors into account: sizes and form of particles of the evaporated powder, the wire or bar diameter; density, specific heat, heat conductivity of evaporated materials, evaporation distance, speed of the burner movement, speed of the wire feeding, the angle of the melted particles dispersion [5 - 7].

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MATHEMATICAL MODEL OF GAS-THERMAL COATING EVAPORATION

The most important factor of designing and controlling the processes of coating evaporation by the method of electric arc spraying is the existence of an adequate mathematical model of the spaying process. The technological scheme of gas-thermal evaporation of a coating is given in Figure 1.

For building the gas-thermal coating evaporation mathematical model let us write down the evaporated material consumption:

$$Q_1 = \frac{\pi \times d^2}{4} V_1 \ / \ \text{m}^3/\text{s} \qquad (1)$$

where V_1 is the evaporation speed / m/s;
π is the mathematical constant value (π = 3,1415...);
d is the burner nozzle diameter / m.

The evaporated coating width can be determined by the formula:

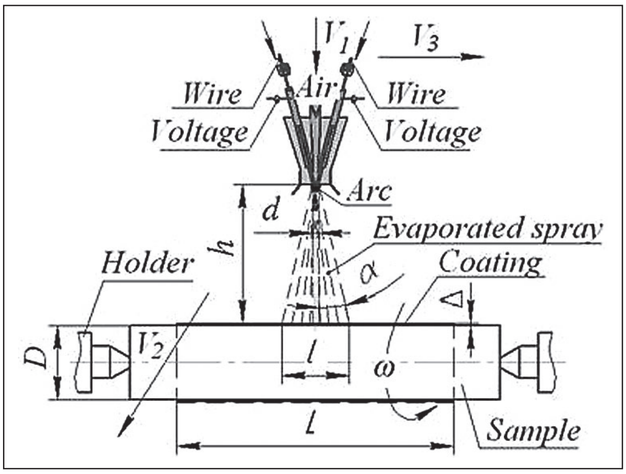

Figure 1 Gas-thermal evaporation scheme: h – evaporation distance; d – burner nozzle diameter; D – part diameter; L – evaporated coating width on the entire shaft length; l – coating width; Δ – evaporated layer thickness; ω –angular speed; α – melted particles dispersion angle; V_1 – evaporation speed ; V_2 – linear speed; V_3 – burner movement speed

$$l = 2 \times h \times tg\alpha + d \;/\; \text{m} \qquad (2)$$

where h is the evaporation distance/ m;

tg α is the melted particles dispersion angle/ degree.

Linear speed V_2 is determined from the expression:

$$V_2 = \frac{\omega \times D}{2} = \omega \times R \;/\; \text{m/s} \qquad (3)$$

where D is the part diameter/ m;

ω is the angular speed or the part rotation speed/ 1/s.

From here we obtain that the evaporation volume is equal:

$$Q = \text{l} \times \pi \times \text{D} \times \Delta = \Delta \times \text{l} \times \pi \times \text{D} = \\ = \Delta \times \pi \times \text{D} \times (2 \times \text{h} \times \text{tg}\alpha + \text{d}) \;/\; \text{m}^3 \qquad (4)$$

where Δ is the evaporated layer thickness/ m;
l is the coating width/ m;
S_H is the evaporation area/ m², determined by the formula:

$$S_H = l \times \Delta \;/\; \text{m}^2 \qquad (5)$$

The volume velocity or the speed of evaporation flow can be expressed through the volume of the evaporated coating Q_2:

$$Q_2 = \frac{Q}{t} = \frac{\Delta \times \pi \times \text{D} \times (2 \times \text{h} \times \text{tg}\alpha + \text{d})}{\text{t}} \;/\; \text{m}^3/\text{s} \qquad (6)$$

where t is the time of operation/ s.

The same value can be expressed in:

$$Q_2 = \omega \times R \times \Delta \times l = \omega \times R \times \Delta \times (2 \times h \times tg\alpha + d) = \\ = \frac{D \times \omega}{2} \times \Delta (2 \times h \times tg\alpha + d) \qquad (7)$$

where R is the part radius/ m.

Substituting equation (3) into equation (7) it is expressed the volume consumption of evaporation Q_2:

$$Q_2 = \text{V}_2 \times S_H = \frac{\omega \times D}{2} \times l \times \Delta = \\ = \frac{D \times \omega}{2} \times \Delta \times (2 \times h \times tg\alpha + d) \qquad (8)$$

The total consumption of the evaporated material is:

$$Q = L \times 2 \times \pi \times R \times \Delta \;/\; \text{m}^3 \qquad (9)$$

where L is the width of the evaporated coating on the entire shaft length/ m.

The volume consumption of the evaporated material Q_3 can be expressed through the total material consumption Q:

$$Q_3 = Q / t = (L \times 2 \times \pi \times R \times \Delta) / t \;/\; \text{m}^3/\text{s} \qquad (10)$$

Q_3 can be also expressed through the burner movement speed V_3:

$$Q_3 = V_3 \times S = V_3 \times 2 \times \pi \times \Delta \times R \qquad (11)$$

At last, equal in equations (1), (8), and (11) it is obtained the kinematic characteristic conformance:

$$Q_1 = Q_2 = Q_3; \\ \frac{\pi \times d^2}{4} V_1 = V_2 \times l \times \Delta = V_3 \times 2 \times \pi \times \Delta \times R; \qquad (12) \\ \frac{\pi \times d^2}{4} V_1 = V_2 \times \Delta \times (2 \times h \times tg\alpha + d) = V_3 \times 2 \times \pi \times \Delta \times R$$

NANO CALC PROGRAM

Based on the presented mathematical model there was developed a program of technological process of evaporation which permits to calculate more precisely the technological parameters with a margin error to 2 %.

This mathematical model permits to calculate the technological process parameters of evaporation taking into account the time and changing the evaporation angle.

There was developed a special computer Nano Calc program containing the above mathematical model for the selection of the optimum technological parameters of the gas-thermal process of coating evaporation (Figure 2).

This technique and the developed program permit to calculate the technological data of the evaporation process for diametrical parts with various overall dimensions, with different basic data. In this program it is also possible to select various materials for evaporation.

Thus, the use of this program and the method of calculating the technological process of the gas-thermal evaporation permits to calculate the technological parameters taking into account the set basic data and on the basis of these calculations to issue the optimum decisions and graphic dependences.

The following data are reflected in this program: selection of parameters, optimum decision, the course of the decision, building dependences, evaporation dia-

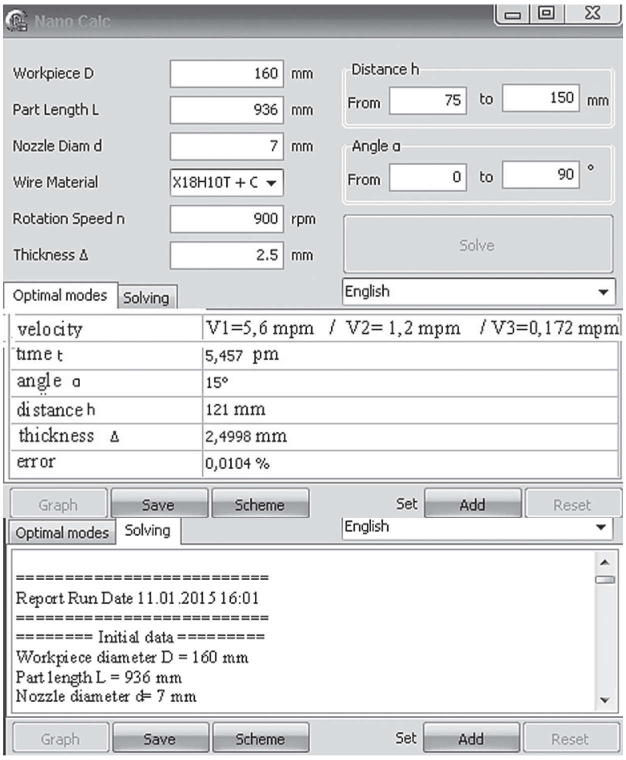

Figure 2 Optimization of the technological process of electric arc metallizing

gram, as well as the possibility to add the data with various evaporation materials for making graphs and dependences.

DISCUSSION OF THE RESULTS

When developing a mathematical model and a program of calculating the technological parameters there were considered the modes of evaporation and characteristics of the material. The thickness of the evaporated layer is defined depending on the evaporation speed, the evaporation distance, and other parameters.

For calculation of the technological parameters of gas-thermal evaporation we will take the following basic data:

- diameter of the burner nozzle d - 7 mm;
- diameter of the part D - 160 mm;
- the width of the evaporated coating on the entire shaft length L - 936 mm;
- evaporation speed V_1 – 5,6 m/s.

The experimental data are presented in Table 1.

Table 1 **Results of the technological calculation**

Parameter name	Variables value						
	$\Delta \times 10^{-3}$/ m						
	2	2,5	3	3,5	4	4,5	5
	ω / rpm						
	800	850	900	950	1000	1050	1100
h /m	0,1365	0,1385	0,1145	0,118	0,1055	0,1295	0,1065
V_2 / m/s	1,067	1,133	1,2	1,267	1,333	1,4	1,467
V_3/ m/s	0,214	0,172	0,143	0,123	0,107	0,095	0,086
α / °	19	14	13	10	9	6	6

By the results of calculation there were obtained the following dependences:

- dependence of the coating thickness Δ on the speed V2 (Figure 3);
- dependence of the coating thickness Δ on the speed V3 (Figure 4);
- dependence of the coating thickness Δ on the set height h (Figure 5);
- dependence of the coating thickness Δ on the rotation speed ω (Figure 6);

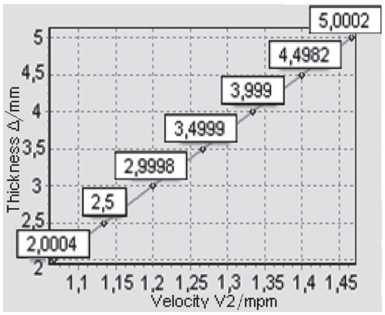

Figure 3 Dependence of the coating thickness Δ on speed V_2

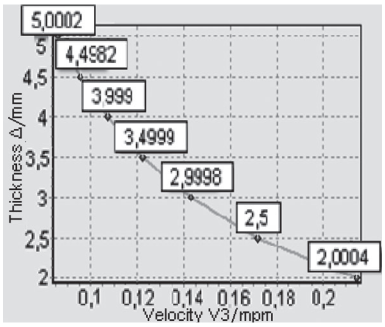

Figure 4 Dependence of the coating thickness Δ on speed V_3

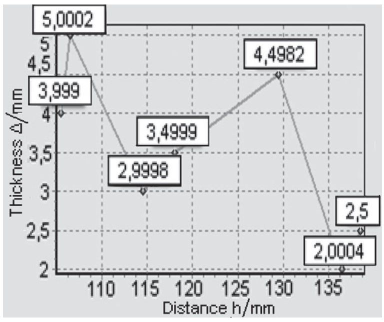

Figure 5 Dependence of the coating thickness Δ on the set h eighth

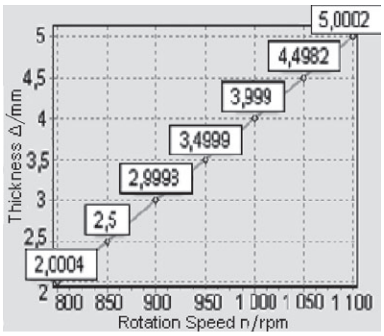

Figure 6 Dependence of the coating thickness Δ on the rotation speed ω

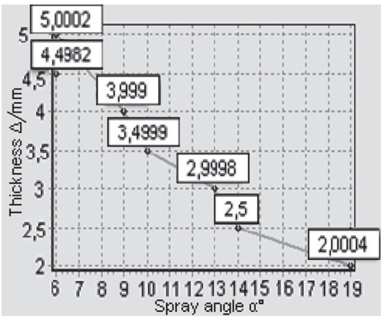

Figure 7 Dependence of the coating thickness Δ on the melted particles dispersion angle α

- dependence of the coating thickness Δ on the melted particles dispersion angle α (Figure 7).

The analysis of the obtained graphic dependences of the gas-thermal evaporation shows that:

- the coating thickness Δ linearly depends on V_2 speed, therefore with the speed increasing the coating thickness increases (Figure 3);
- the speed of the burner movement V_3 significantly effects the process efficiency and the coating thickness (Δ), i.e. the less is the burner movement speed, the thicker is the coating, and it lays down unevenly (Figure 4);
- with increasing the evaporation distance h the loss of the evaporated coating increases and so porosity does (Figure 5);
- with increasing the speed of the part rotation the coating thickness Δ increases (Figure 6);
- the angle of the melted particles dispersion α effects the formation of the evaporated particles flow and the coating thickness Δ. At small angles there is formed the greatest coating thickness, and at big angles the thickness of the evaporated coating decreases to minimum owing to the losses of the evaporated material (Figure 7).

The method of calculation of the evaporation technological process yields satisfactory results for any set parameters.

Using the obtained mathematical model in the developed program, it is possible to define the rational modes of the gas-thermal evaporation which reduce the time for the number of experiments for their selection.

CONCLUSIONS

The most saving and simple way of placing pseudo-alloy coatings is the gas-thermal evaporation.

The mathematical model of gas-thermal coating evaporation considers the evaporation distance h, linear speed V_2, the speed of the burner movement V_3, the melted particles dispersion angle α, the rotation speed ω and permits to determine the coating thickness Δ.

The developed Nano Calc program gives an evident idea of dependences of the mathematical model parameters of the gas-thermal coating evaporation.

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Note: The translation of the N.M. Drag, Karaganda, Kazakhstan