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Calculation and experimental determination of the geometric parameters of the coatings by laser cladding

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Abstract. In the present work the experiments on laser cladding of powder Fe-B-Cr-6-2 on samples of steel 20. Metallographic studies of geometric parameters of deposited layers and the depth of the heat affected zone (HAZ). Using is the method of full factorial experiment (FFE) mathematical dependences of the geometrical sizes of the deposited layers of processing modes. Deviation of calculated values from experimental data is not more than 3%.

1. Introduction

Laser cladding is application on surface of the workpiece coating by melting basis and the filler material [1]. Unlike traditional methods of cladding for restoration of machine parts laser cladding has several advantages. Laser radiation is characterized by the local thermal influence on the material, and as a result, a relatively small thermal influence on the detail altogether. Owing to the fact that laser treatment allows to achieve ultra-high speeds of heating and cooling in the radiating zone, it is possible to reach unique mechanical and tribological properties of the machined surface, which cannot be achieved by traditional methods.

However, it should be noted that laser treatment is a quite expensive method. Equipment and supplies have high cost. Train to perfection of technological process of laser cladding demands large number of experiments. Of great interest is obtaining mathematical model of the process cladding of surfacing, which would allow to determine the parameters of the deposited layer without carrying out additional experiments.

The aim of this work is to obtain regression equations based on experimental data using the method of full factorial experiment to determine the geometrical parameters of the cladding rolls.

2. Materials and equipment

In our experiments the laser system "Kometa-M" equipped with a continuous CO_2-laser [2] was used. For surfacing a powder based on iron Fe-B-Cr-6-2 was used. Samples were made of steel 20 with dimensions 15×20×80 mm. Before cladding, the samples were cleaned off with acetone and dried in an oven at a temperature of 75 °C for 30 minutes. Filler powder material was applied on samples in the kind of a coating. The layer thickness was 0.9–1.0 mm. After application of the coating the samples were dried in the oven at the same modes.

Metallographic studies were performed on the hardness testing of the PMT-3, metallographic microscope Altami MET-1C.

3. Results of experiments and calculations

As factors in mathematical planning was chosen the radiation power *P*, speed of the beam *V* and beam diameter *d*. The responses of the system: the rolls height *H*, width *B*, depth of the zone of thermal influence of the HAZ – *Z*. As an additional discrete factor considered scanning the beam with a frequency *f* = 220 Hz. Surfacing was carried out at the maximum and minimum levels of the factors, which are designated respectively as *z*+ and *z*–. The results of preliminary experiments were chosen the upper and lower levels of factors in which the visually observed formation of deposited layers.

The experiments were carried out in two series – with and without scanning, it is for the accounting of discrete factors of scan. The levels of factors, the quantity of the center z_0 of the plan and the range of variation λ and based on the coded variables from the natural quantities given in table. 1.

Table 1. The levels of factors of the experiment.

Factor	*z*+	*z*–	z_0	λ	Dependence
P, W	1000	700	850	150	x_i=(*P*–850)/150
V, mm/s	9	5	7	2	x_i=0.5(*V*–7)
d, mm	3	2	2.5	0.5	x_i=(*d*–2.5)/0.5
f, Hz	220	0	–	–	–

According to the recommendations [3] as a mathematical model the algebraic linear polynomial of the form is adopted:

$$y = b_0 + b_1x_1 + \dots + b_kx_k + b_{1,2}x_1x_2 \dots + b_{k-1,k}x_{k-1}x_k \quad (1)$$

where is x_i – levels of factors of the experiment, b_i is linear regression coefficients.

According to the method of FFE, the resulting regression coefficients for all the feedback coefficients are substituted in equation (1), made identical to the conversion from coded variables to the natural variables and derived the resulting mathematical model of the form:

$$H, B, Z = f(P, V, d, f) \quad (2)$$

The obtained mathematical model was checked for according adequacy by Student and Fisher criterions. The regression coefficients are presented in table 2.

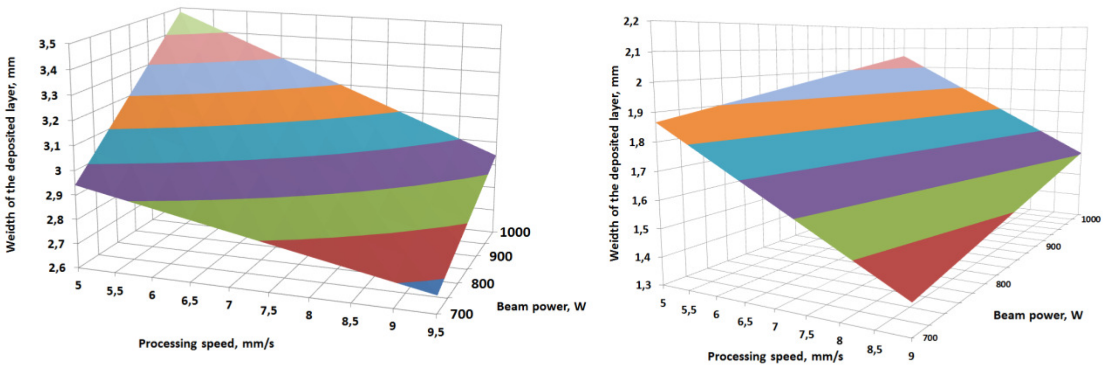
Table 2. The coefficients of regression equations.

Parameter	b_0	b_1	b_2	b_3	b_{12}	b_{13}	b_{23}	b_{123}
H	0.908	0.138	–0.228	0.066	–0.023	0.046	0.0038	–
H_{scan}	0.917	0.035	–	–0.020	0.035	0.017	–0.07	–0.027
B	1.712	0.185	–0.217	–0.107	–0.040	–	0.027	–0.04
B_{scan}	3.170	0.540	–0.255	–0.065	0.200	0.155	–0.100	–
Z	0.387	0.0920	–0.006	–	–0.003	0.028	–0.052	–0.024
Z_{scan}	0.257	0.031	–0.049	–0.007	0.015	–0.004	0.018	–

Removed coefficients are assumed to be zero as non-significant by Student criterion at the significance level α = 0.05 [3].

Analysis of the obtained equations set is directly proportional to the dependence between power radiation and height rolls, and the inverse relationship between speed and height of roller. With the increase of the radiation power without scanning the height rolls increases faster than with scanning, due to the larger area of heat energy distribution of the laser when the high frequency oscillation of the beam. Scanning leads to an increase of the width with simultaneous decrease the height of the rolls and increases the productivity of cladding by 1.3–1.9 times as much. Analysis of the equations for the depth of HAZ shows that the greatest influence on depth of HAZ has the radiation power. The increase of the velocity V leads to a decrease in the depth of the HAZ, due to the smaller momentary energy absorbed by a filler material per unit of time.

According to the obtained mathematical dependences the calculations and obtained data were compared with the experimental results. Built comparative surface defining the relationship between the response and factors the experiment. Comparative surface built for functions B and B_{scan}= f (P, V), when d = 2 mm, is shown (figure 1).



(a) (b)

Figure 1. The dependence of the width of the cushion from the factors of the experiment (a - scanning, b – without scanning).

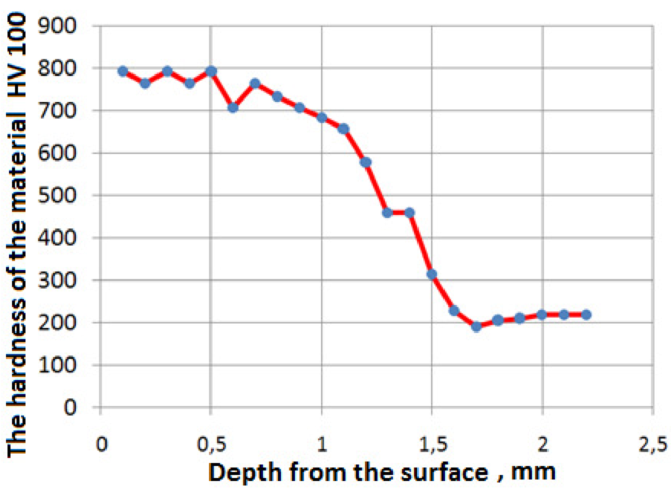


Figure 2. The dependence of micro-hardness on the depth.

According to the data obtained, the nature of the linear dependence obtained in the calculation is the same as that for the experimental values, but the estimated function is growing faster. The deviation of experimental data from calculated is not more than 3%.

Figure 2 shows a typical distribution of micro-hardness of the deposited layer from the surface to the base.

The deposited layer thickness of 0.5 mm has a high hardness of about 800 HV, under it is a HAZ with a hardness of HV 540-720, the thickness of this layer is 0.8 mm, below the follow zone - troostite and sorbitol. The base metal has the hardness 190–210 HV. Notably, the presence of the reflow zone the foundations to a depth of 50–100 µm, indicates high adhesion strength between the coating and the base metal.

4. Conclusion

On the basis of experimental data and mathematical models the surfaces, which allow to estimate the influence of the radiation power, processing speed, diameter of the beam on the geometrical parameters the deposited layers, are constructed. Estimate of the parameters of the deposited layers compared with experimental data the maximum differences do not exceed 3%.

It is established that under high-frequency beam scanning performance the coating process is 1.3–1.9 times as much higher than without scanning the beam.

References

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