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EFFECT OF CLADDING PARAMETERS ON THE HARDNESS OF BIMETAL PLATES

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Hardness is one of the components responsible for the resistance to wear. The development of new materials with hardness surface more than 65 HRC is possible with use welding technologies. High chromium cored wires belong to welding materials that are often used to cladding to protect surface. This article show the problem of determining the important parameters of cladding FCAW to obtain the most hard surface. The use of high chromium cast iron to cladding on to structural steel S235JR showed us how important is knowledge about influence the technological parameters by made this plate and how have a significant impact on the final characteristics surface. For experiment Plackett-Burman design is used.

Key words: bimetal plate, steel / aluminium / coper, welding, hardness, Plackett-Burman design

INTRODUCTION

Advances in material science, metallurgy and welding provides the possibility of using increasingly sophisticated metal materials that are able to move operating parameters higher and higher and increase the life of the machines and equipment. To take advantage of the properties of these materials, the problem of wear must be taken into account at the design stage together with manufacture and operation of machines. The most effective way to counter the consumption is to carry out work on surface welding technology of materials with special properties. One such process is the deposition preventive, used to protect e.g. impact loading plates administrator or sides of the conveyor belts used in the mining industry. In the process of extracting lignite through opencast mining, it is necessary to remove masses of soil and rock appearing on its so - called outlay. The technological system is used for this purpose which includes a wheel excavator, conveyor and spreader. A huge amount of earth masses undergoing the process of mining makes it necessary to use parts with very high resistance to abrasion. In order to reduce consumption, system components are subjected to a process of high chrome alloy surfacing of chromium cast iron structure. Chromium cast iron forming alloys have very high resistance to abrasion, with moderate impact resistance and favorable price-quality ratio. Good abrasion resistance is made possible by the presence of numerous carbides in a relatively soft matrix. The study of high chromium weld microstructure of various cladding methods indicate that they are the most common type of complex carbides $(Cr,Fe)_3C$, $(Cr,Fe)_7C_3$ as well as $(Cr,Fe)_{23}C_6$ depending on the chemical composition of the additive material used for welding [1-4]. It should be noted that the excessive increase in the hardness of the deposit increases abrasive wear. It is a result of a decrease in durability of contact with the surface protected by weld layer. Hardness and microstructure responsible for the resistance to wear. [3-7]

This article presents the problem of the impact of technological parameters in the production of bimetallic plates of the deposited abrasion. The Plackett-Burman plan has been used in the context of the impact of technological parameters on the obtainable hardness of surfacing clad surface layer. [5-7] The Plackett - Burman plan, constructed on the Hadamard matrix, for experiment used (N = 8)

The matrix experiment X is obtained in this way:

$$\begin{bmatrix} N & x_1 & x_2 & x_3 & x_4 & x_5 & x_6 & x_7 & y_i \\ 1 & + & - & - & + & - & + & + & y_1 \\ 2 & + & + & - & - & + & - & + & y_2 \\ 3 & + & + & + & - & - & + & - & y_3 \\ 4 & - & + & + & + & - & - & + & y_4 \\ 5 & + & - & + & + & + & - & - & y_5 \\ 6 & - & + & - & + & + & + & - & y_6 \\ 7 & - & - & + & - & + & + & + & y_7 \\ 8 & - & - & - & - & - & - & - & y_8 \end{bmatrix}$$

Factors are calculated from the program table: B_i, a_i according to Formulas (1, 2):

$$Bi = \frac{\sum_{j=1}^{N} x_{ij} y_j}{\frac{N}{2}} \qquad (1)$$

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$$a_i = \frac{B_i}{2} \quad (2)$$

whereby:

i – variable number, j –experiment number,

x_{ij} – Value i- this variable encoded in j-of this experiment (can assume values +1 or -1 according to the encoded test program),

y_j – the value of the resulting factor j-of this experiment, N – experimental value.

MATERIAL AND METHODS

For the test used a water-cooled table in the sample cladding and additionally laid the pad receiving heat from the space surfacing made from steel, aluminum and copper. As the parent material S235JR steel with a thickness of 10 mm and dimensions of 200 x 400mm was used, and Corodur 61 (C = 5,4 %, Si = 1,2 %, Cr = 29 %, Nb = 3,0 %, Mn = 0,4 %) this wire was used for the cladding. The view of the position and a schematic view of the work table is shown in Figure 1.

The first stage of the paper determines the collections of the factors examined, fixed, distort and outputs.

The set input factors X_i include: $x_1 = V_{NAP}$ – cladding speed / mm/min, $x_2 = \lambda$ – coefficient of thermal conductivity / W/mK, $x_3 = P$ – power source setting / W, $x_4 = L_e$ – the distance between the contact tip and the tip of the electrode / mm.

The set of continuous factors $C_i = (c_1,\ldots,c_n)$ for: c_1 - diameter of cored wire 2,8 / mm, c_2 - test temperature 10 / °C, c_3 - width of bead 35 / mm, c_4 - oscillation speed 0,24 / m/min, c_5 - wire feed speed 5,8 / m/min. The set of output factors $Y_i = (y_1)$ H – Vickers hardness load 294 / N (HV30).

It specifies the test plan and the results are presented in Table 1.

Power control occurs by regulating the voltage setpoint source, which results in a change in the voltage across the terminals of the power source. Whatever it is controlled wire feed speed. On the basis of technological tests the size of the set wire feed was determined.

Sized adopted (Table 1) adorned with research plan input quantities for 8 levels with the central plan according to experiment matrix. The size of normalized thermal conductivity determined X7 was adopted with properties of materials used for heat removal. Individual standardized sizes [- 1, 0, + 1] and corresponding actual size [0,15; 2,15; 4,3] respectively, characterized by coefficient of thermal conductivity the low-carbon steel, aluminum and copper.

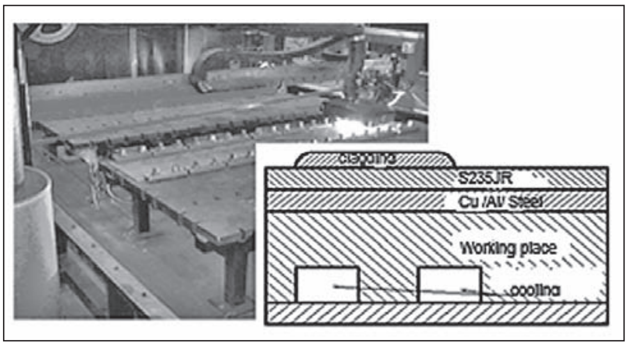

Figure 1 The view position for the automatic cladding and schematic view of the work table. [7]

Table 1 **The size of the actual elimination plan in the initial sample corresponding to the values used in the trials regulated by surfacing technology**

Designation in the initial research plan	Designation of the actual magnitude	Unit of measurement	Calculated size		Accepted size		
			-1	1	-1	0	1
X1	Vnap	mm/min	128,65	195,36	130	160	190
X2	B	mm	24,39	45,61	25	35	45
X3	V osc	mm/s	29,10	47,10	29,6	38,1	46,6
X4	P	W	10 090	12 929	10 045	11 480	12,915
X5	Vd	mm/s	85,40	109,30	88,9	97,4	105,8
X6	Le	mm	19,39	40,61	20	30	40
X7	λ	W/mK	-	-	0,15	2,15	4,3

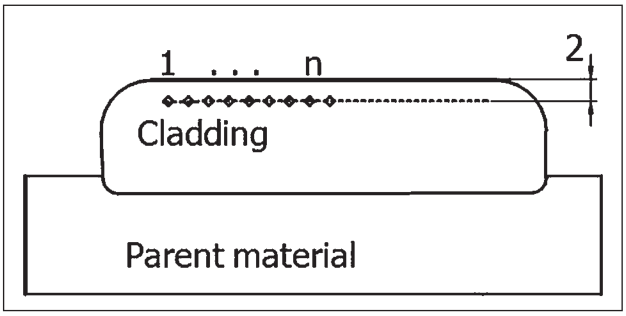

Figure 2 View of choice of places to measure the hardness, and view of test specimen

To check the hardness of Vickers load 294 / N is used [7,8]. Figure 2 shows a view of the selection of the implementation of imprint hardness and view of test specimen.

In table 3 summarizes the results of hardness measurements for each sample and statistical results.[6-15]

Based on the analysis of hardness measurement H (Table 2) it is stated that, that the average value is in the range 842 to 1 125 / HV30 while the average value specified in the plan amounts to 1 005 / HV30 with a standard deviation of 41 / HV30. The most uniform hardness was achieved when measuring the sample number 6 made with the following parameter setting (V_{NAP} = 190 / mm/min, P = 12 915 / W, L_e = 40 / mm, α = 0,15 / W/mK). The largest scattering of the measurements was observed for samples made according to plan number 3: (V_{NAP} = 190 / mm/min, P = 10045 / W, L_e = 40 / mm, λ = 4,3 / W/mK), for which the maximum measured hardness was observed at 1 274 / HV30.

Analyzing the impact of length parameters of free outlet electrodes and cladding speed to the test factor-lower hardness obtained for the short distance between the contact tip and the tip of the electrode and upper

Table 2 **Hardness measurements of the deposit H expressed in the unit of hardness /HV30**

Mearsure-ment no.	Sample no.								
	1	2	3	4	5	6	7	8	9
1	1 089	780	1 274	883	1 109	912	1 052	1 129	1 034
2	1 080	849	1 274	862	1 089	934	1 080	1 080	1 061
3	1 099	829	1 119	869	1 052	919	1 016	1 089	1 034
4	1 061	780	1 089	829	1 034	958	1 034	1 109	990
5	1 070	905	1 099	856	1 034	966	1 016	1 149	1 052
6	1 070	942	1 119	856	1 052	927	1 007	1 061	1 016
7	1 007	912	1 011	817	1 016	927	999	1 099	1 061
8	1 025	974	1 007	804	99	966	999	1 034	1 043
9	1 080	966	1 089	804	990	934	1 034	1 052	1 034
Average sample	1 065	882	1126	842	1 042	938	1 026	1 089	1 036
Standard deviation	30	75,2	91	29,3	39	20,2	27	37	23
Variants sample	901	5 657	8 220	860	1 532	410	717	1 370	510
Popula-tion sample	9	9	9	9	9	9	9	9	9
Min variance	1 007	780	1 007	804	990	912	999	1 034	990
Max variance	1 099	974	1 274	883	1 109	966	1 080	1 149	1 061
Range sample	92	194	267	79	119	54	81	115	71

cladding speed ranges (Figure 3). It can be concluded that the acquisition of lower hardness can be caused by the time to coagulation of carbides being too short, and very fine particles do not fulfill their role in raising the hardness in the soft matrix. This facts is compare by Wang. [3].

In analyzing the impact of a graphical representation of the power and thermal conductivity (Figure 4), you will notice that at low power the source affects the thermal conductivity at obtainable hardness.

It should be also pay attention to the behavior of the hardness values in relation to the higher power settings. In this respect, the influence of the thermal conductivity is less.

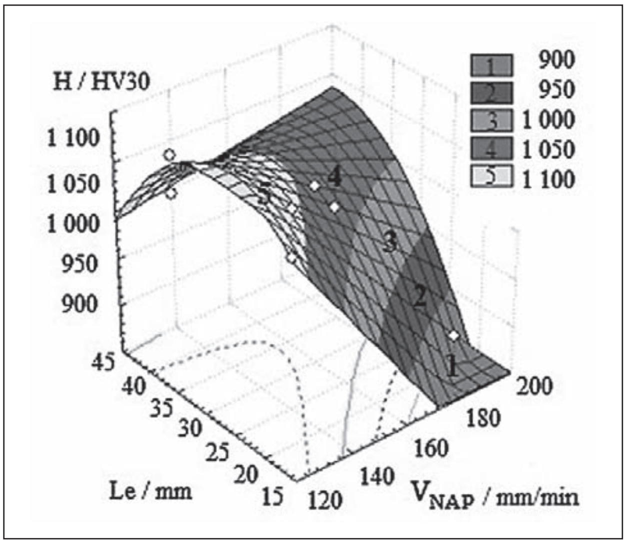

Figure 3 Flow parameters of free outlet electrode of welding speed and hardness

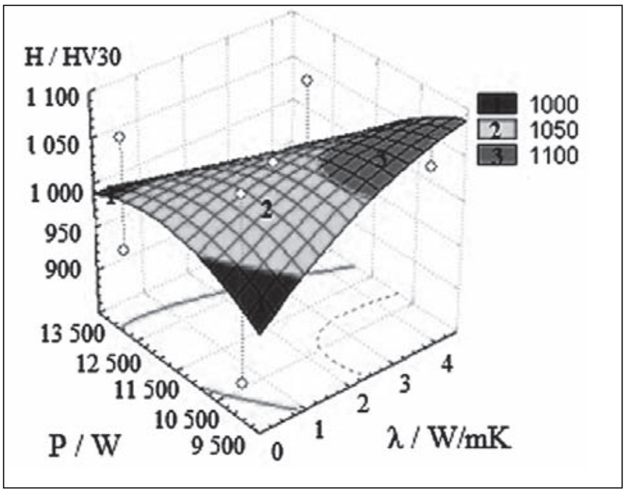

Figure 4 The effects of setting parameters of the power source and the thermal conductivity of the hardness

In order to develop a mathematical model of the process of surfacing wear-resistant flooring describe the relationships between the input and output quantities. The size of the subsidiary adopted the following general form of regression equation in the form (3).

$$y = B_0 + B_1x_1 + B_2x_2 + B_3x_3 + B_4x_4, \qquad (3)$$

whereby: B_i – coefficients of the regression equation.

When changed the mathematical mark with technological parameters we find the equation (3) in the form under:

$$y = 1\ 1001{,}2 + 54{,}2 \cdot V_{NAP} + 7{,}8 \cdot P - $$
$$- 29{,}6 \cdot L_e - 47{,}4 \cdot l \qquad (4)$$

SUMMARY

Applying the plan of experiment allows to precisely define the impact of factors on the final properties. Analyzing the impact of each cladding process parameters we can conclude that the influence of the examined factors on the hardness of the layers obtained are as follows:

The distance between the contact tip of the electrode is of particular importance at higher cladding speeds and reaches the differential hardness of 200 / HV30. For lower process speed the differences in obtained hardness were smaller and amounted to about 50 / HV30 between the extreme settings.

Cladding speed at low range makes it possible to obtained a hardness of more than 1 100 / HV30, when increasing the speed a hardness in the range 850 - 1 050 / HV30 can be obtained and it depends on the settings of other technological parameters.

Settings the source power at low settings allows the use of the parameters of the heat by heat extraction pads made of the steel, aluminum or copper. This can be seen especially for low-power parameters source, where a hardness increase of nearly 200 / HV 30 is observed depending on the process of heat removal used. High settings were obtained for especially for intensive cooling with used the copper plates. If the power sources is increased the influence of the applied heat reception fades. From this it can be concluded that the heat capacity of the cooling plates is not sufficient (10 mm) and their thickness should be increased in the case of higher power settings of source.

The best results of hardness is possible to obtain by low cladding speed middle settings distance between the contact tip and the tip of the electrode , high values of coefficient of thermal conductivity and low settings of the power source.

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Note: The responsible translator for English language is Joanna Łudczak, Pajęczno, Poland