EFFECT OF CLADDING PARAMETERS ON THE HARDNESS OF BIMETAL PLATES

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 surface 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)C, (Cr,Fe)23C6 as well as (Cr,Fe)7C3 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:

\[
\begin{array}{cccccccc}
1 & y_1 & 1 & x_1 & x_2 & x_3 & x_4 & x_5 & x_6 \\
2 & y_2 & + & + & - & - & + & + & + \\
3 & y_3 & + & + & + & - & - & + & - \\
4 & y_4 & - & + & + & - & - & - & - \\
5 & y_5 & + & - & + & + & - & - & - \\
6 & y_6 & - & - & + & + & + & - & - \\
7 & y_7 & - & - & - & + & + & + & - \\
\end{array}
\]

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

\[
B_i = \frac{\sum_{j=1}^{N} x_{ij} y_j}{N} \quad (1)
\]

R. Bęczkowski, Institute of Mechanical Technology, Czestochowa University of Technology, Poland
whereby:

\[ a_i = \frac{B_i}{2} \]  \hspace{0.5cm} (2)

\( i \) – 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: \( x_1 = V_{\text{nap}} \) – 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: \( c_1 = d \) – diameter of cored wire 2.8 / mm, \( c_2 = t \) – test temperature 10 / °C, \( c_3 = b \) – width of bead 35 / mm, \( c_4 = v \) – oscillation speed 0.24 / m/min, \( c_5 = \nu \) – wire feed speed 5.8 / m/min. The set of output factors \( Y_i = (y_i) \) – 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 set-point 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 \( X_7 \) was adopted with properties of materials used for heat removal. Individually 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.

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 (\( V_{\text{nap}} = 190 / \text{mm/min}, P = 12 \, 915 / \text{W}, L_e = 40 / \text{mm}, \alpha = 0.15 / \text{W/mK} \)). The largest scattering of the measurements was observed for samples made according to plan number 3: (\( V_{\text{nap}} = 190 / \text{mm/min}, P = 10045 / \text{W}, L_e = 40 / \text{mm}, \lambda = 4.3 / \text{W/mK} \)), 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
R. BĘCZKOWSKI: EFFECT OF CLADDING PARAMETERS ON THE HARDNESS OF BIMETAL PLATES

METALURGIJA 56 (2017) 1-2, 59-62

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 fact is compared 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.

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).

\[ y = B_0 + B_1 x_1 + B_2 x_2 + B_3 x_3 + B_4 x_4, \]  

(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:

\[ y = 1001.2 + 54.2 \cdot V_{\text{NAP}} + 7.8 \cdot P - 29.6 \cdot L_e - 47.4 \cdot 1 \]  

(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 obtain 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 / HV30 is observed depending on the process of heat removal used. High settings were obtained for especially for intensive cool-

---

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

<table>
<thead>
<tr>
<th>Measurement no.</th>
<th>Sample no. 1</th>
<th>Sample no. 2</th>
<th>Sample no. 3</th>
<th>Sample no. 4</th>
<th>Sample no. 5</th>
<th>Sample no. 6</th>
<th>Sample no. 7</th>
<th>Sample no. 8</th>
<th>Sample no. 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 089</td>
<td>1 274</td>
<td>1 089</td>
<td>1 019</td>
<td>1 092</td>
<td>1 052</td>
<td>1 129</td>
<td>1 034</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1 089</td>
<td>1 274</td>
<td>1 089</td>
<td>1 019</td>
<td>1 092</td>
<td>1 052</td>
<td>1 129</td>
<td>1 034</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1 099</td>
<td>1 119</td>
<td>1 099</td>
<td>1 052</td>
<td>1 129</td>
<td>1 016</td>
<td>1 089</td>
<td>1 034</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1 061</td>
<td>1 089</td>
<td>1 089</td>
<td>1 052</td>
<td>1 034</td>
<td>1 034</td>
<td>1 109</td>
<td>1 099</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1 070</td>
<td>1 099</td>
<td>1 099</td>
<td>1 052</td>
<td>1 034</td>
<td>1 066</td>
<td>1 149</td>
<td>1 052</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1 070</td>
<td>1 119</td>
<td>1 099</td>
<td>1 052</td>
<td>1 034</td>
<td>1 066</td>
<td>1 149</td>
<td>1 052</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1 007</td>
<td>1 011</td>
<td>1 016</td>
<td>1 016</td>
<td>1 092</td>
<td>1 099</td>
<td>1 099</td>
<td>1 061</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1 023</td>
<td>1 007</td>
<td>1 004</td>
<td>1 004</td>
<td>1 089</td>
<td>1 034</td>
<td>1 052</td>
<td>1 034</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1 080</td>
<td>1 066</td>
<td>1 089</td>
<td>1 089</td>
<td>1 092</td>
<td>1 034</td>
<td>1 052</td>
<td>1 034</td>
<td></td>
</tr>
</tbody>
</table>

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 8 60 1 532 410 717 1 370 510

Population sample: 9 9 9 9 9 9 9 9 9

Max variance: 1 007 780 1 007 804 990 912 999 1 034 990

Max variance: 1 099 974 1 034 883 1 109 966 1 080 1 149 1 061

Range sample: 92 194 267 79 119 54 81 115 71

---

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

---

Min variance: 1 007 780 1 007 804 990 912 999 1 034 990

Max variance: 1 099 974 1 034 883 1 109 966 1 080 1 149 1 061

Range sample: 92 194 267 79 119 54 81 115 71

---

Min variance: 1 007 780 1 007 804 990 912 999 1 034 990

Max variance: 1 099 974 1 034 883 1 109 966 1 080 1 149 1 061

Range sample: 92 194 267 79 119 54 81 115 71

---

Min variance: 1 007 780 1 007 804 990 912 999 1 034 990

Max variance: 1 099 974 1 034 883 1 109 966 1 080 1 149 1 061

Range sample: 92 194 267 79 119 54 81 115 71

---

Min variance: 1 007 780 1 007 804 990 912 999 1 034 990

Max variance: 1 099 974 1 034 883 1 109 966 1 080 1 149 1 061

Range sample: 92 194 267 79 119 54 81 115 71

---

Min variance: 1 007 780 1 007 804 990 912 999 1 034 990

Max variance: 1 099 974 1 034 883 1 109 966 1 080 1 149 1 061

Range sample: 92 194 267 79 119 54 81 115 71
ing 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.

REFERENCES


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