CLADDING HARDFACING LAYERS USED TO PROTECT THE SURFACE AGAINST ABRASIVE WEAR

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Abstract

The paper analyzes the influence of the new flux cored wire intended for cladding process by different sets of cladding parameters. Technological parameters of the cladding process such as welding speed, power source setting, the length of projecting portion of the electrode, thermal conductivity coefficient of aluminum for heating dissipation was analyzed. Description of the influence of these parameters was made as a function of the hardness distribution and structure in bead. The results of hardness distribution analysis allow to illustrate the nature of the impact of the examined input variables on parameters of developed surface. The most important parameters of the deposited hard layers here are the hardness distribution and the structure of bead. The cladding processes were conducted by Flux Cored Arc Welding (FCAW). As additional material for cladding material type Fe-Cr-C-with composite was used. To describe the properties of the layers visual test (VT), penetrant testing (PT), Vickers hardness, optical microscope (OM) and scanning electron microscope (SEM) were used. To describe the level of protection the surface against wear the test G65 was conducted.

Keywords: FCAW, Fe-C-Cr, wear, G65, hardfacing

1. INTRODUCTION

Development in materials engineering, metallurgy and welding processes provides the opportunity to use increasingly sophisticated metal materials with special properties. Special materials are capable of transferring the required loads and increasing the durability of machine parts and equipment. The type of wear occurrence must be taken into account at each stage of erection from the design stage through the manufacturing to the final operation. The most effective way to protect against wear is developing the contact surfaces by the use the welding process and additional materials for cladding with special properties. One of these processes is the preventive surfactant with the use of FCAW to protect the work surfaces. Particular application of wear resistant plates is used in the extraction of lignite and aggregate by the open-pit method, where the processes of element wear are intense.

Significant quantities of ground masses subjected to the process of mining make it necessary to use parts with increased wear resistance. In order to minimize wear, the abrasive components are subjected to high-chromium-alloyed castings. Chromium cast iron alloys are characterized by very high abrasion resistance with moderate impact resistance and a favorable price / quality ratio. Increased abrasion resistance is possible due to the presence of numerous carbides in the soft matrix. Microstructure of high-chromium wafers made by various welding methods indicates that the most common are carbides of the type $(Cr, Fe)_3C$, $(Cr, Fe)_7C_3$, $(Cr, Fe)_{23}C_6$ and NbC, Nb_2C and they are dependent on the chemical composition of the additive material used for hardfacing.

It should be noted that an excessive increase in hardness of the welded joint results in an increase in abrasive wear. This is caused by a decrease in the contact life of the cladded layer with the protected surface and consequently leads to its crushing.

Abrasive wear accounts for about 50% of all cavities and is the largest contributor to wear.

The resultant of wear is a set of components, the most important of which is shown in the diagram of Ischikawa (**Figure 1**). Among the five main elements to consider are the type of load, hardness, surface condition, environmental conditions and working conditions [1-12].

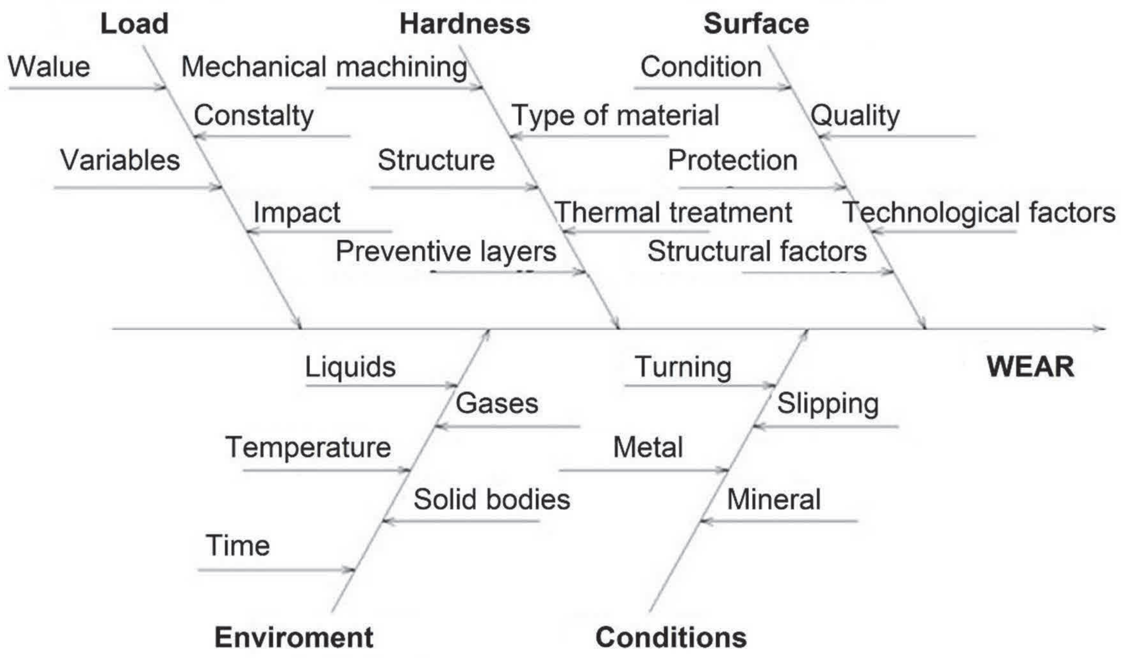

Figure 1 Factors influencing on wear

2. TEST AND RESULTS

2.1. Methodological bases

A cladding machine equipped with a water cooled table covered with aluminum plates to improve heat dissipation from the surfing site was used. The S235JR base material of 10 mm thickness was used for the surfacing tests and the size of a single 200x400 mm plate was used. For welding, a wire of chemical composition (C = 5.4 %, Cr = 29 %, Si = 1.2 %, Nb = 3.0 %, Mn = 0.4 %, B < 1 %). The specified input settings were: power source settings (11480 W), surfacing speed (160 mm / min), protruding electrode length (30 mm), conductivity coefficient for aluminum, (2.15 W / m·K), wire feed speed (5.8 m / min), oscillation speed (2.4 m / min), beam width (35 mm), wire diameter (2.8 mm).

2.2. Experimental part

The samples were completely covered layer with the of 5 mm thickness. The produced plates were tested by visual inspection according to the standard ISO 17637: 2017-02 and penetration tests - ISO 3452-1:2013-08 [13,14]. Subsequently, the samples were subjected to a hardness test on the cross section of the test specimen with the analysis of the distance from the top layer to each measuring point. Vickers method was used in accordance to standard ISO 6507-1:2005 at 98.1 N (HV10) [15]. After polishing and nitrifying, samples were prepared for observation on optical microscopy. Samples were also analyzed on a scanning electron microscope with the EDS X-ray microanalysis.

The sample was subjected to a wear test according to ASTM G65. The standard describes a laboratory procedure for determining the abrasiveness of metallic materials using a rubberized friction wheel and dry quartz sand. The result of the abrasion resistance test is the loss of material removed by the abrasive in mm^3 [16].

2.3. Results and discussion

The **Figure 2** shows the results of measure hardness distribution HV10 of the distance (mm) from the top surface of the bead. Hardness was measured in several points. The highest values of hardness were observed on the top of samples. Below the hardness values were in range from 800 to 1000 HV10. In the mixed zone the hardness went down to the values from 450 to 650 HV10. Hardness values of the parent material were in range from 175 to 225 HV10.

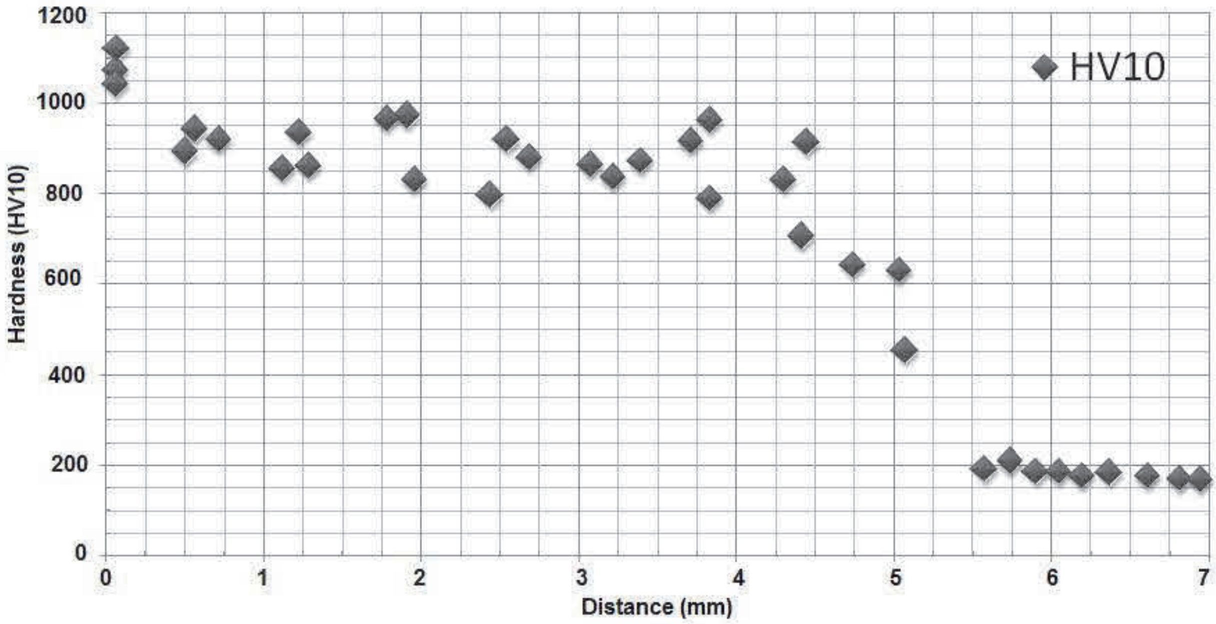

Figure 2 Hardness distributions depending on the distance from the top

Visual and penetrant tests show surface imperfections such as cracks. These cracks are stress relieving in the sample.

Metallographic tests were conducted on polished micro-sections etched in 3% alcohol solution of nitric acid (nital).

Figure 3 shows the structure of carbides in all parts of the clad. **Figure 3a** shows view of structure in the layer of clad. The distribution of carbides near fusion line (**Figure 3b**) and parent material (**Figure 3c**) is shown.

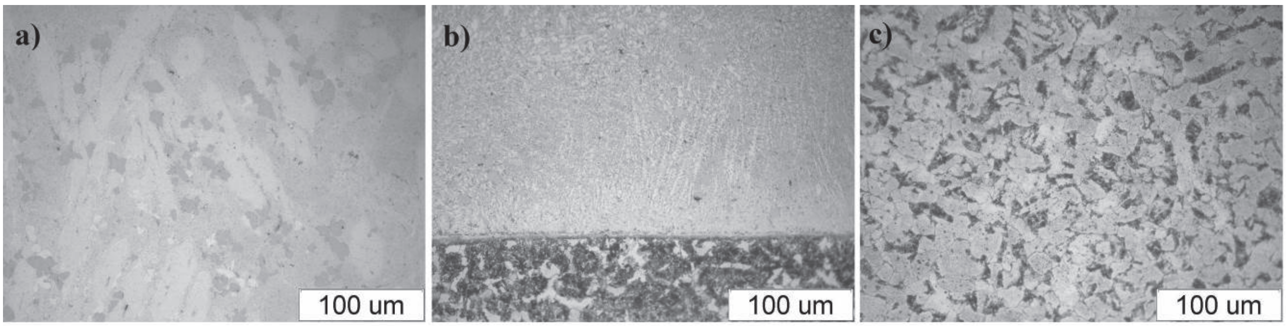

Figure 3 Structure of the hardfacing plate

The chemical composition was determined by X-ray microanalysis EDS using a scanning electron microscope equipped with a Hitachi S4200 ray EDS detector. **Figure 4** shows the SEM surface analysis of hardfacing layers, with the presence of Fe, Cr, Nb, Si and C. Given the chemical affinity it should be assumed that in the material there are niobium and chromium carbides.

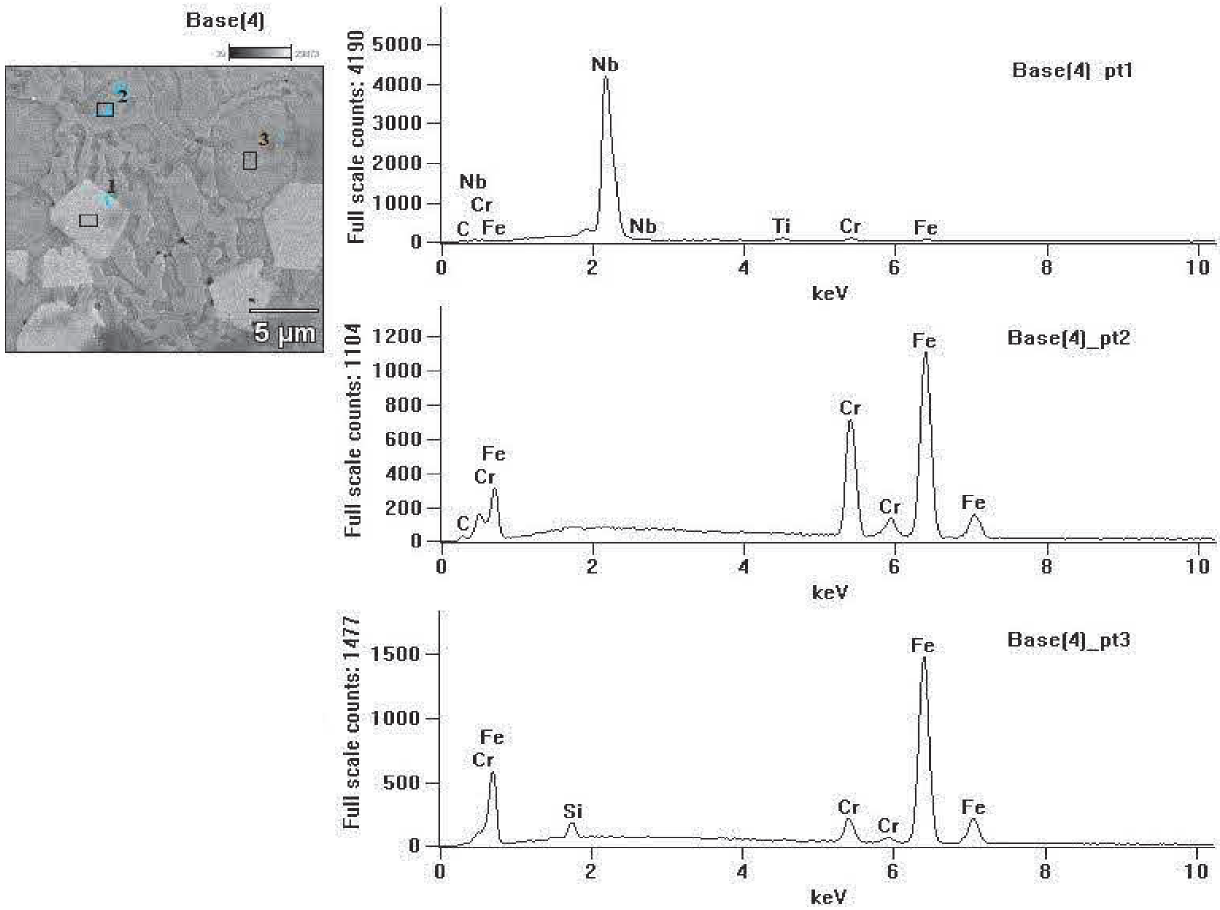

Figure 4 SEM analysis of the microscope

Taking into account the chemical affinity of these elements it can assumed that niobium and chromium carbide are most likely to occur in the material (**Figure 4**). Due to the accepted research methodology, the share of coal should be estimated. **Table 1** shows the weight of the elements, and **Table 2** shows the atomic content of the elements.

Table 1 Number of Weight (%)

	C	Si	Ti	Cr	Fe	Nb
Base(4)_pt1	2.8		1.3	1.9	2.3	91.6
Base(4)_pt2	1.5			25.0	73.5	
Base(4)_pt3		1.6		5.7	92.7	

Table 2 Number of Atom (%)

	C	Si	Ti	Cr	Fe	Nb
Base(4)_pt1	17.7		2.1	2.8	3.1	74.3
Base(4)_pt2	6.5			25.0	68.4	
Base(4)_pt3		3.1		6.0	90.9	

Wear tests were performed using ASTM G65 A procedure. The test data were: load 130 N, velocity 200 rpm, wear distance 4309 m, aggregate flow 345 g / min, density 7.86 g / cm^3, initial mass 170.611 g, final mass 170.508 g, weight loss 0.103 g, volume loss 13.104 mm^3. The use of increased heat reception from the place of surfacing gives the expected results in terms of increased wear resistance. The most favorable result was obtained from the expected volume loss. In the analyzed publications, the minimum volume loss is 18 mm^3 [17, 18] and is over 10 times lower with the use of hard-wearing plates - 185 mm^3 [19]. In literature, minimal mass loss from 0.1519 g [17] and from 0.18 g [18, 20] were observed. The analyzed case confirms the assumptions from the work [21] that the using cooling allows to reach the best wear resistance.

3. CONCLUSION

Hardness distribution was checked in dozens of points and the results of this test show that on the top of specimen the hardness is the highest, in the middle section hardness goes down and by the parent material value of hardness goes up, but still is over than to 800 HV10. Surprisingly, in the middle section of clad, hardness is lower than in the top section. Normally, the bottom section made by mixed clad with parent material has the lowest hardness. In this case using additional aluminum plate gives the quickest heat dissipation. The measure points of the hardness in the mixed zone is through all thickness of the layer on the same level. With detailed analysis of the hardness distribution, we can observe measurements in the lower part of the weld with slightly increased values. This may be caused by larger clusters of niobium carbide deposits in this zone.

Observations with the optical microscope (**Figure 3**) show the principal axes of the distribution of carbides in the direction of heat dissipation. This is especially noticeable for chrome carbide due to the elongated nature of the excrement. Niobium carbides are finer than chromium carbides, and their distribution is not regular. There are places with small areas of niobium carbides - in the top of specimen and areas with a high proportion of niobium carbides. Their presence depends on the area of the bead. The increase of the share of niobium carbides was observed over the line of fusion, which was proved by hardness measurements.

Tests performed with the use of a scanning electron microscope (SEM) with X-ray and chemical composition allow to conclude that the multiphase layer is deposited, and it is composed of chromium, niobium and silicone carbides. This information is confirmed in studies of surface distribution of elements included in the weld hardfacing layers and forming areas with different phase composition.

Wear tests allowed to assess the deposits in durability. The layers developed with using FCAW allow to obtain a highly resistant layer based on the complex carbide structures by intensive cooling in an economical way.

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