THE EFFECT OF THE HARDFACING SEQUENCE ON THE STRUCTURE AND EROSION RESISTANCE OF HIGH CHROMIUM ALLOY

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Abstract

The present work is focused on the influence of the hardfacing sequence on the structure and erosion resistance of deposited layers. In the researche one type of the additional material with high content of 3.8 %C and 22 %Cr was used. The process of hardfacing was made by the flux cored wire arc welding (FCAW) with 2 types of welding sequences. There were implemented string beads and weave bead. The analyzed hardfacing welds showed significant differences in the tested properties. This is due to the nature of the deposition process of the string bead and weave bead. Hardfacing made with string beads had numerous chromium carbide type precipitates of (Fe,Cr)7C3 that is characteristic for the materials deposited on the structure of chromium cast irons. The structure of the hardfacing made with weave bead was characterized by dendritic structure. The differences in the hardness measured in these layers were up to 270 HV. Erosive wear tests were carried out with using corundum and a modified position of the jet milling and with 2 impingement angles.

Keywords: Wear resistant alloys, hardfacing, erosion, welding sequence, hardness

1. INTRODUCTION

The hardfacing is one of the more efficiency techniques of protection machinery equipments and constructions against different wear conditions. The erosion with solid state particles can be considered in many engineering systems involved in mining industry and transport system. The welding technologies as for example SSAW (Self Shiedled Arc Welding) are one of the much more economical solutions for creating effective wear protection surface to apply hardfacing Fe-C-Cr alloys. Thanks to their good wear resistance and low cost, iron-based hardfacing alloys are frequently employed in industry to extend the service life of components subjected to abrasive, erosive or metal to metal wear conditions, such as rocking pulverizing, crushing to applications and transport systems [1-8]. The excellent abrasive and erosive wear resistance of the weld depositions of iron-based hardfacing alloys, with respect to manufacturing cost, is primarily depends to the formation of hard M_7C_3 carbides. The problem is that brittle and coarse M_7C_3 chromium carbides tend to separate from the matrix during the wear process, the efficacy of the application of these iron-based hardfacing alloys to parts exposed to heavy external impacts is limited. However, if instead of primary M_7C_3 carbides in the structure of the weld pad will be smaller, harder and uniformly distributed, abrasives cannot effectively penetrate into the matrix and carbides not easily separable from the matrix. In this way wear resistance of iron - based alloy hardfacing under heavy external influences can be improved. Therefore, many researchers the addition of strong carbide forming elements such as W, V, Nb, Ti and B is added to the melt in order to obtain other types of carbides as for example MC-type , which are smaller and harder than the M_7C_3 carbides [7,9-10]. Other way to obtain different size and types of carbides is the change of the hardfacing techniques and their parameters. There are many welding techniques such as oxyacetylene gas welding (OAW), gas metal arc welding (GMAW), shielded metal arc welding (SMAW) and submerged arc welding (SAW) that can be used for hardfacing. The most important differences among these techniques lie in the welding efficiency, the weld plate dilution and the manufacturing cost of welding consumables. In the application of hardfacings, self shielded fluxed cored arc welding (SSAW) is one of the most interesting techniques. This kind of hardfacing presents greater productivity than coated electrodes and greater flexibility than with a submersed arc and in addition to this, present lower thermal input, less distortions, and less thermally affected zone. The self-shielded flux cored arc welding process aggregates the main advantages of the GMAW such as high values of deposition rate, yield, and the work factor of the welder, enabling high productivity and high quality weld to be obtained [9,11-14]. The method of self-shielded flux-cored wire welding involves melting flux-cored wire and metal substrates from the heat of an electric arc burning between the metal wire tube, comprising a core powder, and the weld object. The components of the core wire provide gas and metal vapour deposition insulating zone than atmosphere. During the melting of the core is also generated slag, which covers a thin layer of liquid metal droplets transferred from the wire to the molten weld pool. The slag that is formed during the melting process is primarily responsible for protecting the welding arc and molten weld pool from the atmosphere. Due to low cost and acceptable performance, iron-chromium self shielded core wire for coatings are being widely preferred. These alloys are based on the high chromium white cast irons of hypoeutectic and hypereutectic compositions. In alloys of the hypoeutectic composition, the microstructure of the coating consists of primary dendrites of austenite surrounded by eutectic mixture of austenite and finer carbides. In alloys of the hypereutectic composition, primary carbides grow as rods or needles and are embedded in the eutectic matrix. The present research work has the main goal in examinations of microstructure properties on the erosion behaviour of one type of hardfacing alloy deposited with different parameters of hardfacing process.

2. EXPERIMENTAL PROCEDURE

Non-alloy structural steel of designation S235 for general purpose was selected as parent material for hardfacing layers. The thickens of deposited steel plate was 6 mm. Self shielded cored wire with a diameter of 1.2 mm and the chemical composition specified by the manufacturer in **Table 1** was selected for hardfacing. The deposition process was carried out on using an Cloos Quinto Profi welding source.

Table 1 Chemical composition of material used for hardfacing, wt%

C	Cr	V	W	Fe
3.8	22	0.8	0.8	balance

The process of deposition was carried out in two embodiments using a string beads and the weave bead. The hardfacing process parameters are shown in **Table 2**. The specimen buildup string beads designated as S, specimen made with weave bead as V. In the case of string beads surfacing was made by 6 beads per length of 200 mm. Weave bead was made as a single bead of the same length. In both cases the final width of hardfacing was 40 mm and the height of the hardfacing was up to 4 mm.

Table 2 Hardfacing process parameters

Specimen	Voltage (V)	Current (A)	Width of bead (mm)	Wire speed feed ($m \cdot min^{-1}$)
S	22-23	170-180	5	4.3
W	22-24	130-150	35	4.3

Samples for metallographic examinations were taken from the cross section of the coating. Deposit has been subsequently tested with metallographic optical microscope Olympus GX51 and hardness tests with Vickers method. The study of structure was performed using metallographic reagent MI19Fe. Erosive wear tests were carried out on a modified position of the jet milling. Ejector nozzle diameter was 6 mm, and its distance from the sample was fixed at 6 mm. Tests were carried out with use of a fixed pressure jet erosion at 6 atmospheres. As a material for erosion was used corundum. Specimen before the test were cleaned and weighed and then assembled into the device and erosion tests were carried out at 30° and 45° and last 10 min. The time of erosion test was determined on the basis of earlier trials, which made it possible to determine how much time is reached the level of consumption set. After 10 minutes the samples were removed from the machine, cleaned stream of air and reweighed to the nearest 0.001 g.

3. RESULTS AND DISCUSSION

The results of metallographic investigation of the obtained welds show large differences in the structure of deposited layers. Hardfacing made with string beads (**Figures 1** and **2**) had numerous chromium carbide type precipitates of $(Fe,Cr)_7C_3$ that is characteristic for the materials deposited on the structure of chromium cast irons [15,16]. Precipitations of the carbide had varied shape and placement of the cross-section of the deposit. There are visible cracks in the mixed area of deposited material and base material. These cracks are caused by high stress in mixed zone and high hardness of this material. There were no observed cracks in the hardfacing made with weave bead. The image exhibits the carbide rods along and across the long axis. Near the weld deposit/base metal interface area, there exists a small region of eutectic microstructure. Above this zone, majority of the primary rod like carbides are aligned orthogonally to the surface of the base metal. Nonetheless, in some areas, the primary carbides have grown with random orientation.

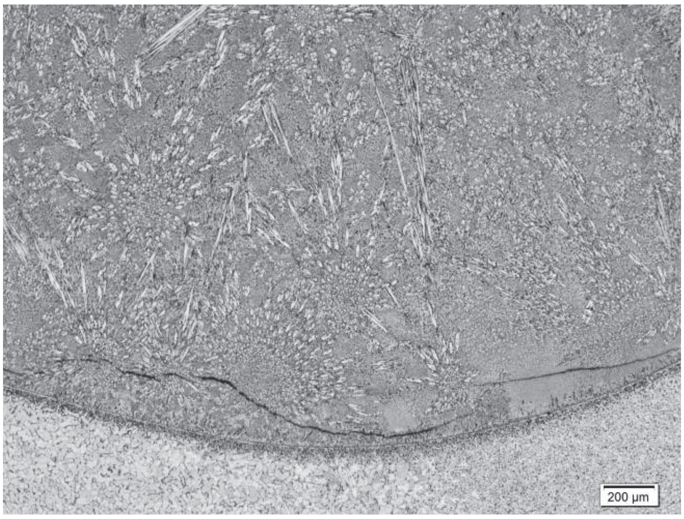

Figure 1 Structure of coating made with string bead,magnification x50

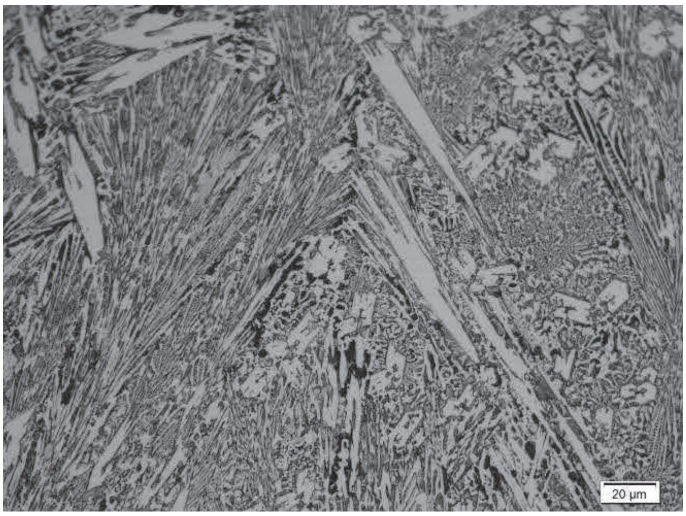

Figure 2 Structure of coating made with string bead, magnification x500

The hardfacing made by weave bead is characterized by a different structure of the deposit (**Figures 3** and **4**). In this case, the structure of the entire cross section of the weld is of a dendritic with individual carbide precipitations of shape similar to a sphere. In this sample, dendrites growing mainly in direction of heat flow can be observed all over the coating, as can be seen in **Figure 3**. Crystallization in non-equilibrium conditions causes flow of carbides existing in the core wire in most to a solution and enriching eutectic interdendritic areas. Hardness testing confirmed the differences in the structure of the obtained welds. In **Figure 5** are shown the results of hardness test performed on the cross-sectional welds. Studies were carried out in each case in the middle of the sample, and the results show the differences of up to nearly 270 HV10. The average hardnes for specimen made with string bead is 957 HV10 and for specimen made with weave bead is 686 HV10. Hardness for the deposit weld by string beads are higher by nearly 40% of the sample weld by weave bead. It is noted that for specimen marked as S hardness in excess of 1000 HV10 was observed in the central area of the weld rich in carbides. In the external beads hardness was lower and fluctuated in the range of 850 - 900 HV10. It would be useful to correlate the microstructures of these hardfacing layers to their erosion resistance. Following are the results of erosion test which were used to evaluate and compare coatings properties.

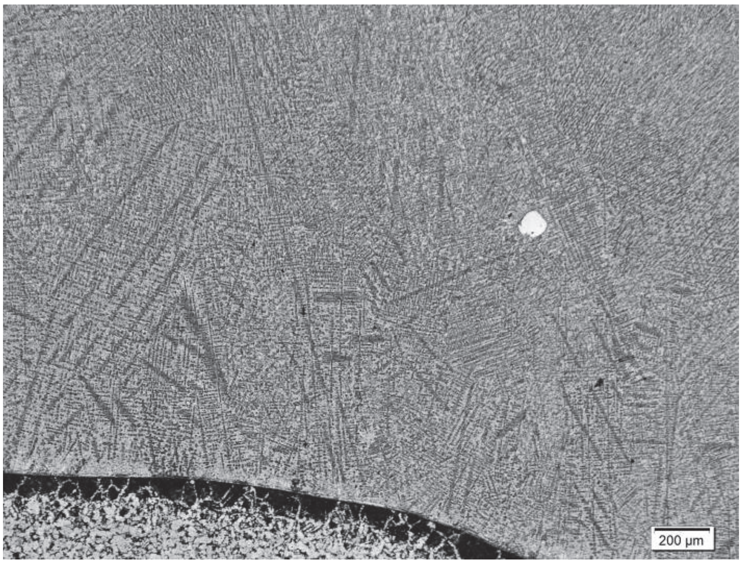

Figure 3 Structure of coating made with weave bead, magnification x50

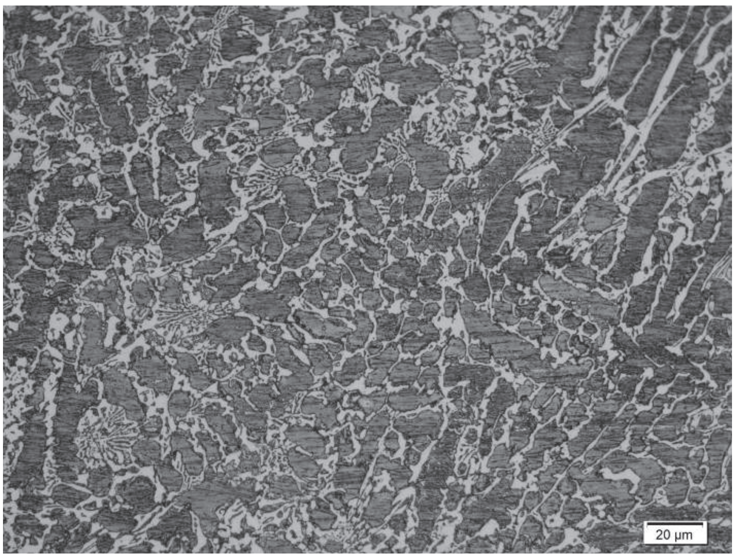

Figure 4 Structure of coating made with weave bead, a) magnification x50, b) magnification x500

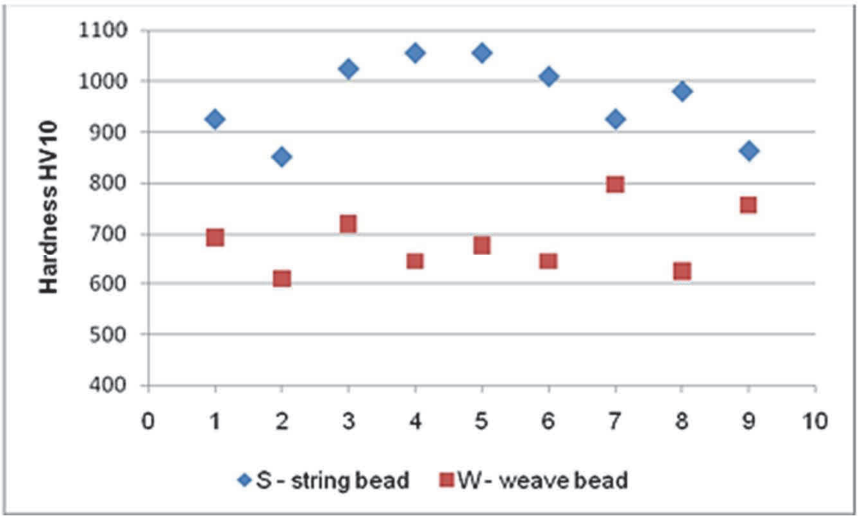

Figure 5 Hardness distributions in hard facing

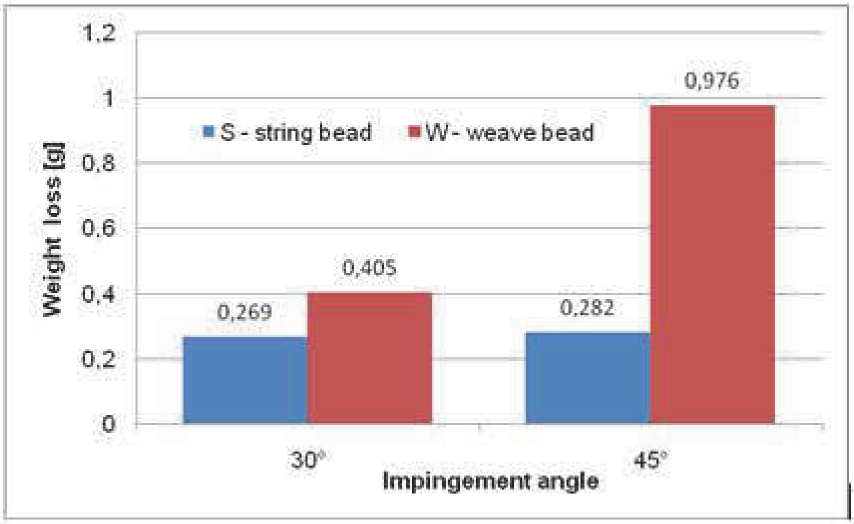

Figure 6 Results of erosion tests

The research on the erosive wear resistance showed that the highest wear resistance has specimen S made by using string beads. **Figure 6** shows the results of studies on the erosive wear. At a both of impingement angles the wear resistant were significant higher. The hardfacing made with weave bead occurred vulnerable for changing the impingement angle of erosive test. In this case for the 45° impingement angle the wear was more than 2 times higher. The results of the present investigation suggest that characteristics of weld hardfacing depend upon the relative hardness deposited layers which in turn decides the relative contribution of matrix and the carbides to the erosion process. The dependence of erosion rate on impingement angle for hardfacing high chromium iron alloys was found to be strong, in case of the hardfacing made with weave bead.

4. CONCLUSIONS

1) The dependence of erosion wear on impingement angle was in general weak for weld hardfacing made with string bead. For the hardfacing made with weave bead erosion wear has significant dependence on impingement angle.

2) The erosion wear of weld hard facing layers can be rationalised in terms of relative hardness of the structure under given erosion conditions.
3) Significant differences were seen in the structure of hardfacing made with different sequence of welding.

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