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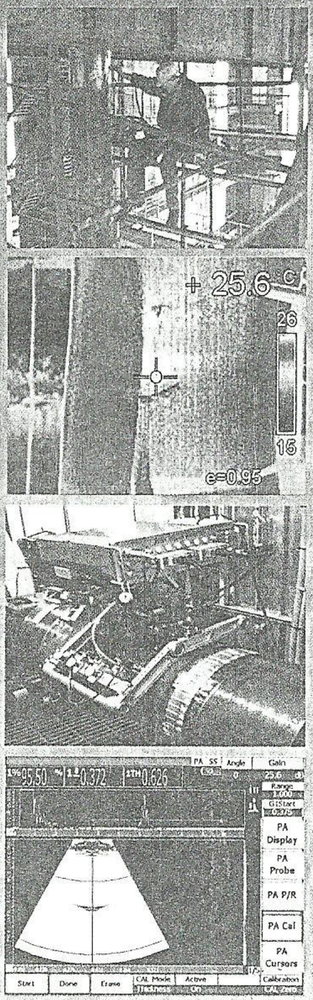

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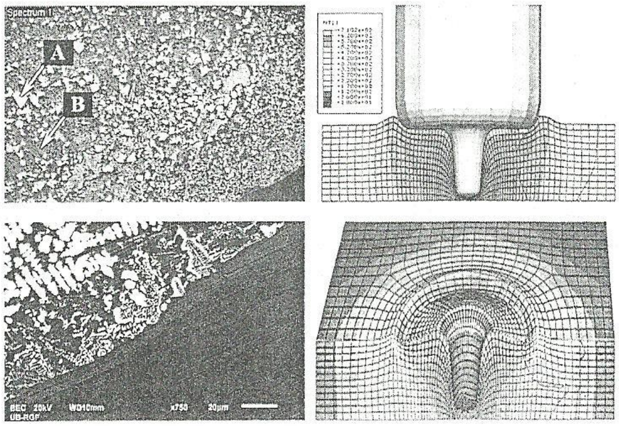

Sudarea şi Încercarea Materialelor

Abstracts

Numerical simulation of the plunge stage in friction stir welding - different tools

H. Daşcău, A. Sedmak, M. Rakin, D. Veljić, M. Perović, B. Medjo and N. Bajić

This paper investigates the plunge stage using two different tools in the numerical simulation. The first tool have a conical shoulder with angle of 10° and the second tool have a flat shoulder. The welding plate in the numerical model is dimension 50 x 50 mm and 6mm in thickness. A coupled thermo-mechanical model was developed to study the temperature fields of alloy AA5083-H116 under rotating speed of 400 r/min, during the friction stir welding (FSW) process. A three-dimensional finite element model (FEM) of the plunge stage was developed using the commercial code ABAQUS to study the thermo-mechanical processes involved during the plunge stage. A coupled thermo-mechanical 3D FE model using the arbitrary Lagrangian-Eulerian formulation, the Johnson-Cook material law and the Coulomb's Law of friction.

In this analysis, temperature, displacement and mechanical responses are determined simultaneously. The heat generation in FSW can be divided into three parts: frictional heat generated by the tool shoulder, frictional heat generated by the tool pin, and heat generated by material plastic deformation near the pin region.

Tools consist of a shoulder and a pin. The design of the shoulder and of the pin is very important for the quality of the weld. The pin of the tool generates the heat and stirs the material being welded but the shoulder also plays an important part by providing additional frictional treatment as well as preventing the plasticised material from escaping from the weld region. Numerical results indicate that the maximum temperatures of the plunge stage in friction stir welding are higher by using tool with a flat shoulder than by using tool with a conical shoulder for the same rotation speed. The plasticised material is extruded from the leading to the trailing side of the tool but is trapped by the conical shoulder which moves along the weld to produce a smooth surface finish.

Structural and mechanical properties of different hard welded coatings for impact plate for ventilation mill

A. Alil, B. Katavić, M. Ristić, D. Jovanović, M. Prokolab, S. Budimir, M. Kočić

Ventilation mill for grinding coal is one of the main steam power plants in the system that makes a significant influence on the level of energy efficiency with its work. Working parts of the device during exploitation are dominantly exposed to intensive abrasive and erosive wear and also to impact loading at elevated temperatures, which can lead to damage and fracture of homogeneous materials, thus shortening their working life. The consequences are the reduction in mill production capacity and its ventilatory effects compared to the projected value, as well as frequent delays due to parts replacements, that significantly affects the productivity, economy and energy-efficiency of the system.

In order to determine the optimal technology for revitalization of the damaged impact plates the experimental model-hardfacing was engaged and different technologies and additional materials were used. Three technologies arc-hardfacing were applied (MMA, SMAW and gas welding - G) and eight additional materials with different chemical composition and properties (Fe-Cr-C-Si, Fe-Cr-C-Si-Ti, Fe-C-W-Co-Ni-Si, Fe-Cr-W-B-Nb-Mo-C, W-Fe-C and WC-Ni-Cr-Si-B). The aim of this paper is to make the selection of optimum welding procedures and additional materials and hardfacing technology definition based on the results of structural and mechanical properties of samples of experimental model hardfacing. Cutting the samples for mechanical and structural tests is performed with water jet cutting using hardfaced test plan. Investigation of its macrostructure has been done, diagrams of distributions of hardness have been made, zone of the surface layer and HAZ-a, and the degree of mixing for all hardfaced samples have been defined. In addition, microstructural analyses were obtained with optical (OM) and scanning electron microscopy (SEM). The choice of additional materials and hardfacing procedures which were applied in the hard facing impact plates ventilation mill has been made based on the results of this research paper.

Solid-state diffusion bonding

C. Voican, C. Stănescu

Diffusion bonding, as a subdivision of both solid-state welding and liquid-phase welding, is a joining process wherein the principal mechanism is interdiffusion of atoms across the interface. Diffusion bonding of most metals is conducted in vacuum or in an inert atmosphere (normally dry nitrogen, argon or helium) in order to reduce detrimental oxidation of the faying surfaces. Bonding of a few metals which have oxide films that are thermodynamically unstable at the bonding temperature may be achieved in air.

Laser welding process of stainless steel used for biomedical applications

K. Colić, S. Petronic, A. Sedmak, A. Milosavljević, Z. Kovacević

Stainless steel materials that are used in biomedical applications were analyzed in order to investigate the applicability of laser welding to the fabrication of biomedical devices. Grade 316L is the modified molybdenum-bearing grade, the low carbon version of 316 , with a maximum amount of the carbon content of 0.03%, for better corrosion resistance to chloride solution and to minimize the sensitization. The minimum effective concentration of chromium is 11% to impart corrosion resistance in stainless steels. The maximum amount of 4% of molybdenum in this alloy, gives 316 better overall corrosion resistant properties than other austenitic stainless steels, particularly higher resistance to pitting and crevice corrosion in chloride environments. It has excellent forming and welding characteristics, thus it is commonly used for a variety of parts for applications in the industrial fields. In biomedical applications it is suitable for temporary implant devices such as fracture plates, screws, and hip nails, and as material for some medical devices.

Implanted medical devices must function flawlessly and they must have an aesthetic quality that helps with sterilization and does not irritate the tissue. The welds on these implantable must be a hermetic seal very close to heat sensitive components and since the value of the component before welding is very high, the yield from the welding process must also be high. Laser welding meets these requirements, as this welding method produces a smooth hermetic seal. Laser welding of stainless steel biomaterials is used for all biomedical applications, where is of importance that parts must be joined with smooth welds without pores. Laser welding is a high energy-density, low heat-input process with specific advantages over conventional fusion welding processes. These include high welding speed, narrow heat affected zone, low distortion, ease of automation, single-pass thick section capability and enhanced design flexibility.

In this paper, stainless steel 316L sheets were welded by pulsed Nd:YAG laser, without filler material. The mean laser power was 160W, peak power 7.5 kW and max energy 80 J. Parameters of laser process were: laser energy 48 J, pulse duration 6.0 ms and pulse frequency 5.5 Hz. Mechanical properties of welded joint were determined by tensile test. Grade 316L also has outstanding welding characteristics. Post-weld annealing is not required when welding thin sections. The microstructural changes were observed by scanning electron microscope and analyzed by energo-dispersive spectrometry. Microstructures of based material, weld, HAZ and fusion zone were discussed.

Dissimilar friction stir welding of EN AW 6082 - EN AW 5083 aluminium alloys

R. Gabor, R. Cojocaru, C. Ciucă, L. Boţilă

The welding of aluminium and its alloys is realized using traditional electric arc welding, which requires expensive special precautions.

- FS welding procedure allows an easily processing of the similar and dissimilar aluminium alloys, is an environmental friendly process and has various economical advantages.

The experimental program for dissimilar FSW of EN AW 6082 and EN AW 5083 (both used especially in civil engineering), has demonstrated that the two alloys are weldable with FSW, using the proper welding parameters and a welding tool with proper geometrical characteristics and dimensions.

Here are presented the welding parameters, the results of the experimental tests and also the evaluation of the experimental results: macro-analysis, hardness measurements, tensile tests and bending tests.

Considering the special precautions, needed for the aluminium alloys welding using the typical electric arc welding processes, the results of dissimilar FSW of EN AW 6082 - EN AW 5083 aluminium alloys may be considered for some industrial applications.

Structural and mechanical properties of different hard welded coatings for impact plate for ventilation mill

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Keywords

Ventilation mill, impact plate, hardfacing technology, hard welded coating, structural properties, mechanical properties

1. Introduction

Hardfacing is a surface treatment method to improve the surface properties of metal, in which a welding metal that has excellent resistance to wear and oxidation is homogeneously deposited onto the surface of a substrate [1]÷[4]. Many examples of hardfacing materials tend to be alloys containing hard carbides [5].

In practice, the repair welding is applied for the revitalization of homogeneous and welded components in order to protect them and extend their life. The damaged metal must be replaced with new undamaged, so that the work life for all components satisfy safety requirements to the next full control. Each revitalization of hardfacing is a unique process, so in practice there are no standard procedures for defining and applying the most optimal technology of reparation by hardfacing or the assessment of remaining life of repaired components. A special problem is a complex procedure of checking the quality of hardfaced sample. Process optimization of working of the plant, in this case the ventilation mill is achieved by the necessary correlation between the technological process and condition of working parts.

Deviation from the required working parameters can widely be a result of damaged working parts, as evidenced by the size of interval of the ventilation effect of the mill. Revitalization of these components by welding, or hardfacing is increasingly being applied to power plants. As the importance of revitalization of welding in the maintenance of power plants becomes bigger and bigger, beside the procedures, the new additional materials are being engaged that provide longer lifetime of parts exposed to wear with its structural - mechanical properties. The final goal of modern technologies for revitalization is that the life of a component, or appropriate material from which it is made, is at least equal to or longer than predicted, or that is really possible to define periods of regular control.

In the case of ventilation mill there is predominantly abrasive wear and erosion at elevated temperatures [6]. In many applications, where excellent wear resistance and sufficient impact resistance are required, hardfacing alloys modified with the composite particles may be advantageous, as the presence of composite powders in the microstructure of hardfacing alloys may improve their wear resistance without greatly sacrificing toughness [5]. Experimental research indicates a linear dependence of abrasive wear resistance and mechanical properties of materials. Specifically, based on the mechanical properties, especially hardness, the behavior of metals in the conditions of wearing can be predicted. The depth of penetration of the abrasive particles with high hardness is inversely proportional to the hardness of the surface layers. However, hardness is not the only characteristic that affects the wear resistance and wear in general. Parameters, which also affect the hardness wear resistance, are the structure, shape, size and distribution of microconstituents in the welded layer. Microstructural components in proportion to its hardness, the relative share and the distribution, affect the level of resistance to wear. Based on previous research, it can be concluded for the intensity of abrasive wearing affect the following factors: the nature and characteristics of the abrasive, aggressive working environment, the operating speed and load, and material properties of working parts, or their contact surfaces [2]÷[4]. In addition, the intensity of abrasive wearing increases with increasing the temperature above the critical value. Based on above mentioned parameters, we select the additional materials for the revitalization of parts by hardfacing.

In recent years, in the area of resistance to abrasion and erosion, the technologies of surfacing have been developed or are developing, which use more complex materials alloyed with Cr, Mo, Nb, W, V, Ti, B, Co and other elements [1]÷[5]. The nano technology is used in making any additional materials. Full chemical composition in not known for the certain number of additional materials in aim to protect them from the competition.

In addition, unlike the traditional technologies, in the implementation of some additional materials the heat treatment is not used before and after model hardfaced samples. Besides the price of model hardfaced samples, this certainly affects the ability to perform model hardfaced samples, which is often limited by performing heat treatment before and after model hardfaced samples. Practical advantages are reflected in the higher operational and easier performance process with less volume of testing during revitalization by hardfacing. However, before applying these materials in the exploitation conditions, it is necessary to test model hardfaced samples in order to test the recommendations.

One group of additional layers of materials for hardfacing resistant to abrasion are alloys based on Fe and Ni, which contain the following elements: C(%) 0.2-7.5; Cr(%) 5-40; Ni(%) $\leq$ 4 or without Ni, Mn(%) $\leq$ 4 or without Mn ; Mo(%) $\leq$ 9 or without Mo, W(%) $\leq$ 9 or without W, V(%)$\leq$ 10 or without V, Nb(%) $\leq$ 10 or without Nb and others. The second group of additional materials are so called hard metals, composites with a matrix based on Fe and Ni and WC particles of different shape and size [2] ÷ [5].

The main goal of this research is, beside the known hardfacing alloys from the system of Fe-Cr-C, the conquest of the application of new additional complex materials alloyed with Cr, Mo, Nb, W, V, Ti, B, Co and other elements. Defining technical requirements and procedures for revitalization and expanding the knowledge in the the field of repair hardfacing work pieces ventilation mills. By applying these technologies it would reduce the number of possible emergency repairs and it would prolong the period to complete the necessary repair facilities, which would achieve significant economic effects and also increase the energy efficiency of thermal power plants.

2. Experimental part

The additional materials used in this study were Fe-Cr-C-Si, Fe-Cr-C-Si-Ti, Fe-C-W-Co-Ni-Si, Fe-Cr-W-B-Nb-Mo-C, W-Fe-C and WC-Ni-Cr-Si-B manufactured by Castolin Eutectic Co., Ltd, Vienna. The Table 1 presents the hardfacing procedures, signs and nominal chemical composition of additional materials, which are used in hard facing test samples. Hardfacing was carried out on samples which were hot-rolled steel sheet S355J2G3. 200 x 250 x 15 mm, in one, two and three coats.

Hardfacing was carried out under the following conditions (Table 2) depending on the procedure and the type of additional material. In Figure 1 the appearance of welded samples is shown.

Table 1. Additional materials and hardfacing procedures

Hardfacing electrode	Nominal chemical compositions	Process hardfacing
5006	Fe- Cr-C- Si	MMA
4541 EC	Fe-Cr-C-Si	MMA
6710	Fe-Cr-C-Si/Ti 0.2	MMA
4010 EC	Fe-Cr-C-Si/Ti 0.18	MMA
Ultim 112	Fe-C-W-Co-Ni-Si	MMA
DO*48	W- Fe-C	SMAW
390N DO	Fe-Cr-W-B-Nb-Mo-C	SMAW
7888 T	WC-Ni-Cr-Si-B, matrix with WC	G

Table 2. Condition of hardfacing

MMA	d electrode (mm)	3.2; 4; 5
	I (A)	100 - 180
	U (V)	16 - 55
	v (cm/min)	10 - 12
	En (kJ/mm)	1.2 - 4.8
	Tp (°C)	160 - 170
SMAW	d wire (mm)	1.6
	I (A)	110 - 170
	U (V)	19 - 30
	v (cm/min)	10 - 41
	En (kJ/mm)	0.3 - 2.4
	Tp (°C)	160 - 170
	Vgas (l/min)	12 - 16
G	d wire (mm)	1.6
	Vgas (l/min)	1.5 - 1.7
	Tp (°C)	160 - 170

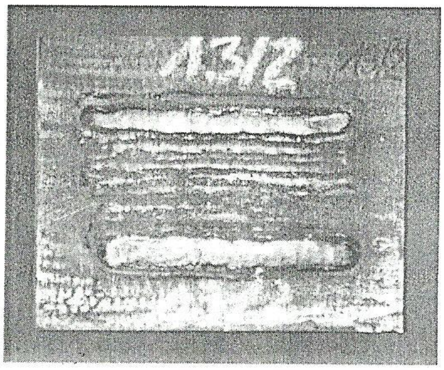


Figure1. Hardfaced sample with two layers (4541EC)

Before testing the model, hardfaced samples are preheated at Tp = 160-170 °C and cooled in ambient air.

3. Microstructual analysis and hardness test

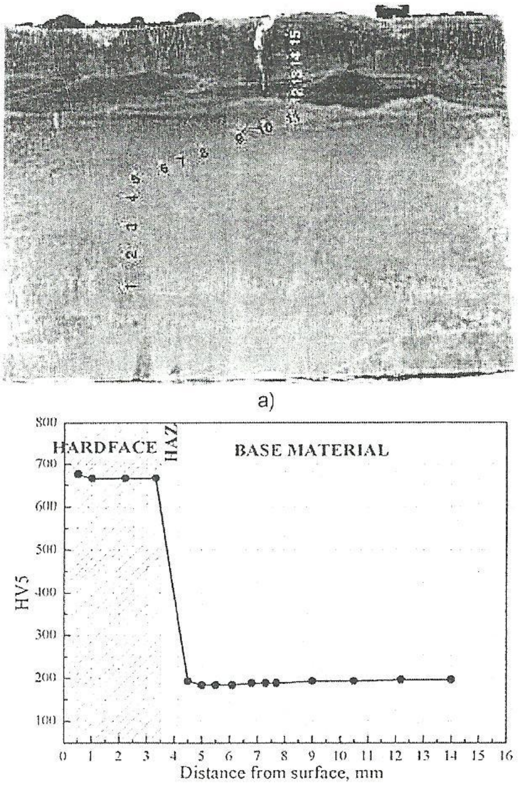
The microstructures of the hardfacing alloys were analyzed, and their hardness were evaluated. Cutting the samples to analyse the structure and hardness was carried out by the water jet on the plane perpendicular to the surface of hardface. Structural tests were carried out on polished samples etched with a solution of 3pct Nital (macrostructure) and 60 cm^3 HCl + 20 cm^3 HNO_3 + 40 cm^3 glycerin (microstructure) with standard optical microscopy (OM) and scanning electron microscopy (SEM) with EDS. Also, the measurements of hardness in the cross section of hardfaced samples was made (Vickers HV5). Based on the results the diagrams of hardness distribution have been made and the zone of hardface, HAZ and base material, as well as the degree of mixing for all hardfaced samples has been defined.

4. Results and discussion

Figures 2a and 3a show the measurements of the macrostructure of samples hardfaced with two layers, with additional material 4541EC, and the three-layers DO 390N, and the Figures 2b and 3b show the measurements of the distribution of hardness in the zone of hardface, the transition zone and the base metal.

The numbers of layers, the average thickness of hardface, the degree of mixing and hardness of hardface were given in Table 3, depending on the type of additition material and process of hardfacing.

The low degree mixing of 11% is achieved in a double layer hardfaced samples with alloys 5006 (MMA) and 390NDO (SMAW). Surfacing patterns in three layers hardfaced samples SMAW process with alloys 390N DO and DO 48 get the lowest degree of mixing of 5 and 12%. In all welded samples is an obvious decrease the hardness layer with increasing thickness layer and number of layers. Decrease in hardness is the result of slower cooling of layer. The maximum of hardness is achieving by welded with alloy Ultima 112 (MMA) and 390N DO (SMAW). Beside that, the variation in harddness can be explained by the distribution of the different phases along the depth of the hardfacing deposit, as was evident from microstructural investigation (Figures 4 ÷ 6).



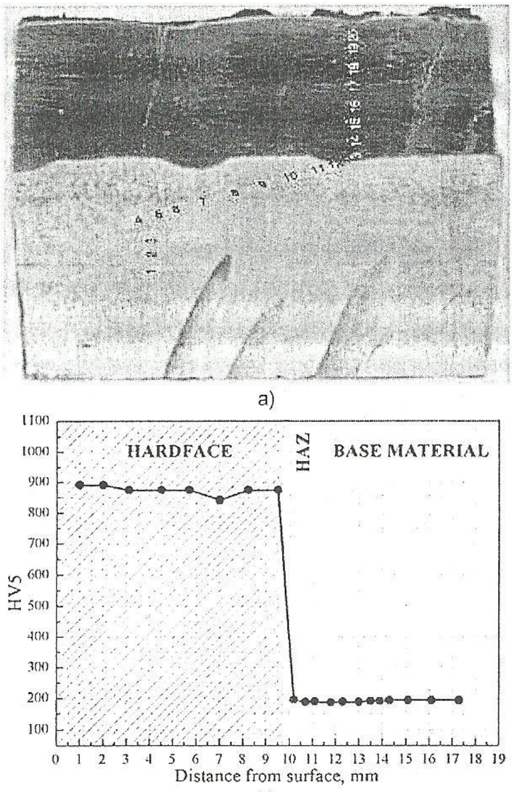
a)

b)

Figure 2. a) macrostructure and b) distribution of hardness in cross section of the sample hardfaced with MMA in two layers with additional material 4541 EC

Table 3. Characteristics of hardface

Addition material	Number of layers	Thickness, [mm]	Degree of mixing, [%]	Hardness, HV5
5006	1	3.1	28	487-781
	2	5.2	11	644-701
4541 EC	1	2.5	27	739-739
	2	3.5	26	666-677
6710	2	7.2	21	841-874
	3	9.8	19	677-739
4010 EC	2	6.8	22	781-810
	3	8.4	13.5	701-874
Ultim 112	1	2.7	62	1027-1120
	2	3.7	44	825-966
DO*48	2	3.5	23	739-781
	3	7.1	12	766-781
390N DO	2	7.0	11	927-946
	3	9.7	5	841-891
7888 T	1	1.6	33	644-677



a)

b)

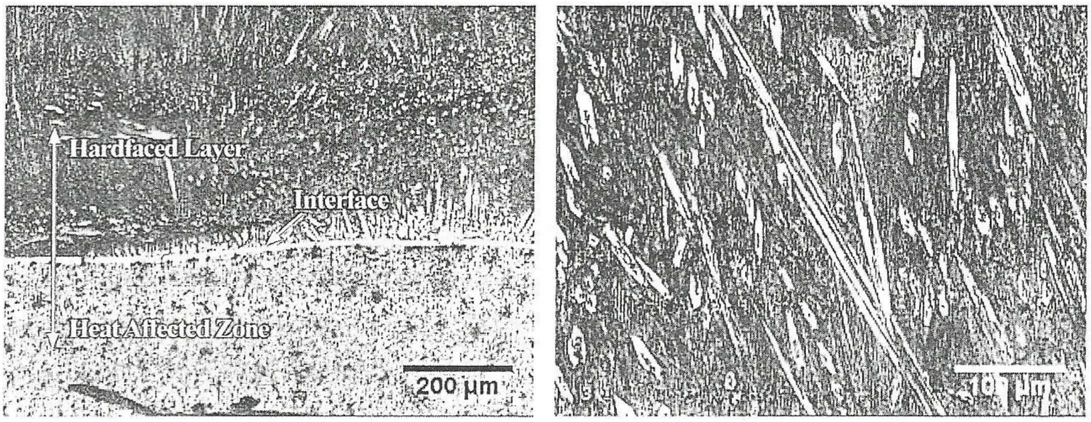
Figure 3. a) macrostructure and b) distribution of hardness in cross section of the sample hardfaced with SMAW in three layers with additional material 390N DO.

Figures 4, 5, 6 and 7 are an optical micrograph of the hardfaced samples after etching. In 5006 hardface sample a larger number of primary carbide rods sizes from 50 to 250 micrometers is present, than in the samples 4010EC and 390N DO. It has been reporeted that large primary carbides, which are indentified to be (Cr, Fe)7C3, are formed from the melt of the hardfaced electrodes and exhibit columnar growth with a hexagonal cross section [7]÷[9].

Beside that, the samples hardfaced 4010EC and 390N DO show a homogeneous distribution of carbide and complex carbide polygonal and spherical [5], [7]÷[9]. As the complex carbide fraction increases, hardness and wear resistance improve [1]÷[3]. The microstructures of hardfaced specimens were observed by an scanning electron microscope (SEM) and their chemical compositions were examined by energy-dispersive spectroscopy (EDS). Figure 7 (a) through (c) are SEM micrographs with EDS of the hardfaced layer (a and c) heat-affected zone HAZ (b) of hardfaced electrode Ultima 112.

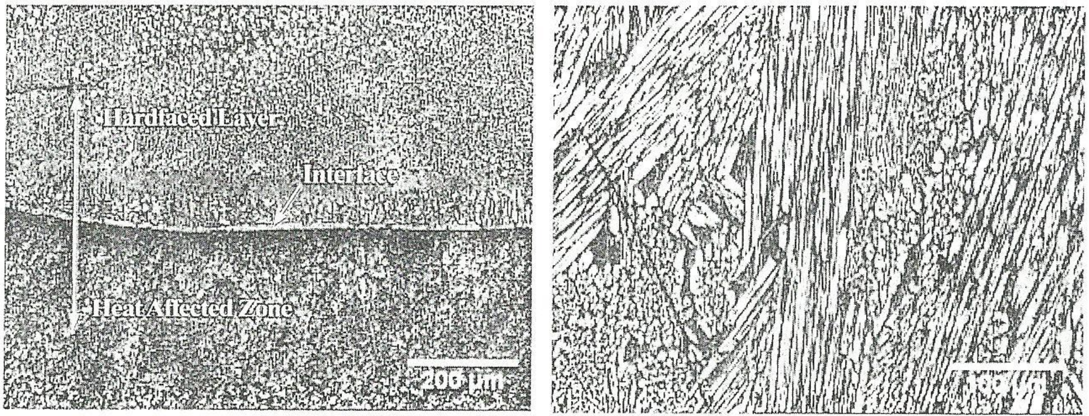
The EDS date shown in Table 4 indicate that hardfaced layer is phase with high content of W, Co and C. Deposit contains a high density of tungsten carbide (WC) in a ferrous based matrix (M) with increased hardness.

The chemical composition and the morphology (Figure 7 and Table 4) suggest that phase A is fine WC carbide and B is primary austenite with eutectic carbides [7]÷[9]. Tubular electrode developed for extra hard coatings (68-72 HRC) on alloy and low-alloy steels [7], [9]. Recent studies have shown that an increase of retained austenite in the martensite - carbide structure increases resistance to wear regardless the same drop in hardness [1]÷[3], [7]÷[9].



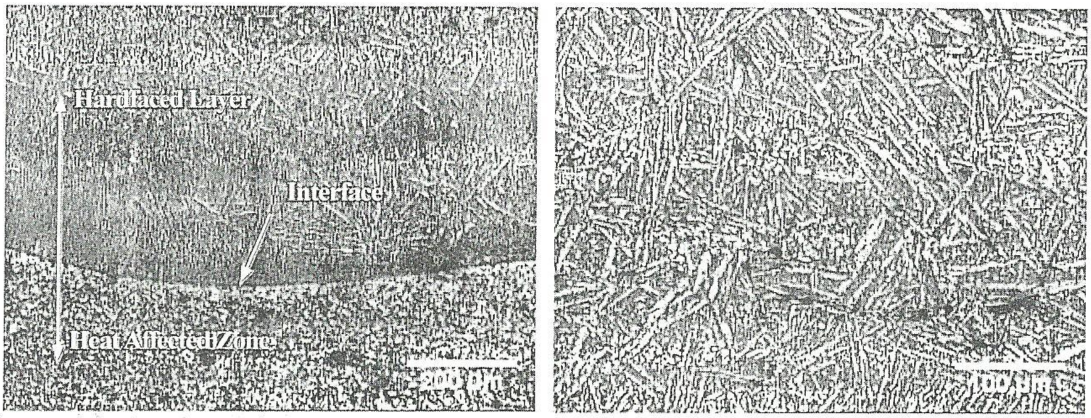
a) b)

Figure 4. Optical micrograph (OM) of sample hardfaced with two layers of alloy 5006:
a) basic material - hardface, x100, b) surface of layer of hardface, x200



a) b)

Figure 5. Optical micrograph (OM) of sample hardfaced with three layers of alloy 4010 EC:
a) basic material - hardface, x100, b) surface of layer of hardface, x200

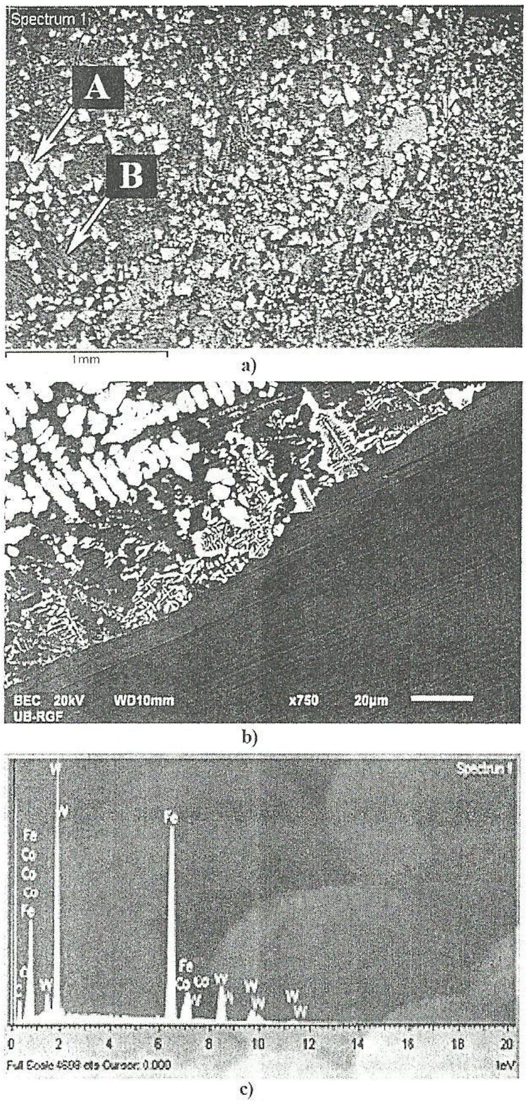


a) b)

Figure 6. Optical micrograph (OM) of sample hardfaced with three layers of alloy 390N DO:
a) basic material - hardface, x100, b) surface of layer of hardface, x200

Table 4. Chemical composition of the phases in alloy Ultim 112, mas %

Phases	C	Si	Fe	Co	Ni	W
HL	9.74	0.48	45.89	3.62	0.42	40.27
WC	13.19	0.00	1.41	0.00	0.00	85.40
M	7.67	0.80	79.69	5.60	0.50	5.75



a)

b)

c)

Figure 7. SEM micrograph of: a) hardfaced layer, b) heat-affected zone HAZ and EDS of Ultim 112 sample

5. Conclusion

Test of the structure and hardness hardface samples hardfaced by different procedures and additional materials indicated the following:

1. Increase in thickness or number of layers of hardface reduces the degree of mixing and hardness of hardface.
2. In the microstructure of hardface carbides were noticed with different shape, size and composition depending on the chemical composition of additional material. In white irons with high contents of Cr carbides in the dominate form of bars, and in alloys alloyed with Ti, W, Nb, B, Mo, etc. there are also complex of polygonal carbides and spherical sizes.
3. Hardface hardness increases with a greater presence of complex carbides of polygonal and spherical sizes. It can be assumed that in this way the resistance to wear will increase,too.

Acknowledgments

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