Archives of Materials Science and Engineering

Volume 46
Issue 2
December 2010
Pages 108-114

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Structure analysis of welded joints of wear resistant plate and constructional steel

M. Adamiak [a,*], J. Górka [b], T. Kik [b]

[a] Division of Materials Processing Technology, Management and Computer Techniques in Materials Science, Institute of Engineering Materials and Biomaterials, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland

[b] Department of Welding, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland

* Corresponding author: E-mail address: marcin.adamiak@polsl.pl

Received 06.09.2010; published in revised form 01.12.2010

ABSTRACT

Purpose: Purpose of this paper was to understand the structure and chemical composition changes of gas metal arc welded joints of wear resistant plate with constructional steel plate with possible application as replacing material for reservoirs and chute in cement industry. Based on the experiment results presented it is clear that welding of wear resistant plate with constructional steel is possible, but special attention is needed during the welding process of the root.

Design/methodology/approach: Wear resistant plates can be used for elements working in intensive abrasion resistance conditions to obtain considerable material and economical savings based on the manufacturing costs reducing and decreasing turnaround time for replacing worn parts. During the welding process of two materials, when one is wear plate and the other is steel plate significant structure changes and mixing of alloying components in weld area are observed.

Findings: Based on the experiment results presented it is clear that welding of wear resistant plate with constructional steel is possible, but special attention is needed during the welding process of the root, most of important changes during welding of wear resistant material are connected with melting, mixing and carbides passage into weld area, non uniform chemical composition of the welded joint creates different microstructures with different hardness.

Practical implications: Welding of wear resistant plate with constructional steel is possible, but special attention is needed during the welding process of the root. Root weld must be free of cracks and possibly free of intermixing with wear resistant plate material. Applying welding parameters described in the paper is possible to achieve free of cracks root, presence of crack in face weld is not important in term of wear resistance abilities of chute.

Originality/value: Development of new generation materials, which allow intensive use in machine parts with extended life-time is clear in demand especially when considering the economic aspects. Technological progress of new materials and new solutions for the future should be carefully and precisely analysed.

Keywords: Welding; Wear plate; Microstructure

Reference to this paper should be given in the following way:

M. Adamiak, J. Górka, T. Kik, Structure analysis of welded joints of wear resistant plate and constructional steel, Archives of Materials Science and Engineering 46/2 (2010) 108-114.

MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

Development of new generation materials, which allow intensive use in machine parts with extended life-time is clear in demand especially when considering the economic aspects. Technological progress of new materials and new solutions for the future should be carefully and precisely analysed. Another aspect to consider relates to the implementation part of a new generation materials with high resistance for abrasion wear (wear resistant plates, sheets and pipes). The wear resistant materials, have their special properties thanks to specific, complex manufacturing process, found application in metallurgical, mining, automotive industries and also during the manufacturing and exploitation of machine parts working in heavy operation conditions. Wear resistant plates are distinguished by good weldability, impact resistance and also good to machining and plastic forming, thanks to high metallurgical purity. Furthermore, it is possible to join high hardness with resistance for dynamic loads action. Wear resistant plates can be also used for loads transfer in some conditions. Wear resistant plates can be used for elements works in intensive abrasion resistance conditions to obtain considerable material and economical savings based on the manufacturing costs reducing and decreasing turnaround time for replacing worn parts [1,2]. Possibilities for the application of these materials are wide and not completely known. At present, there is a high probability for intensive growth of their application because of accurate technological properties well as clear identification of and operation features. Wear resistant plates are multilayer lining with high abrasion and erosion wear resistance connected with easy assembling. Usually they are produced by covering weldable carrier plate with wear resistant alloyed or cermets deposit. There are two methods of manufacturing very durable coatings - arc surfacing and diffusion bonding of cermets powders using vacuum furnace [3,4]. Independently from the manufacturing process, wear resistant plates show very high quality of conformance and repeatability of properties on sheets from the same type [5,6]. Expected resistance for abrasion wear can be obtained by using surface layers with complex carbides phases (1500-3000 HV), with hardness 2 to 3 times higher compared to then popular abrasive materials. Very important factor to increase durability of wear resistant layers is related to the ordered arrangement of hardening phases. Possibilities for the control of surfacing process and crystallization of surfaced allows to increase the durability of wear resistant plates, independently from chemical composition and hardness of used phases. Wear resistant plates can be cut by using plasma, bended and joined to create fragments of lining or parts in machines [6]. Wear resistant plates can be used not only as a plain elements, but also thanks to good weldability of base layer and bend possibilities up to 400 mm in diameter, they can be used for manufacture of complex construction [7-16].

2. Experimental work

In cement industry very often elements of reservoirs and chutes, exposed to intensive abrasion wear, are replaced by new materials with increased abrasion wear resistance. Appropriate welding technology has to be established for using of this type elements (easy weldable constructional steel element and element with strongly limited weldability because of high carbon equivalent). During the welding process of two materials, when one is wear plate and the other is steel plate significant structure changes and mixing of alloying components in weld area are observed. The main purpose of this work was to understand the structure and chemical composition changes of gas metal arc welded joints of wear resistant plate with constructional steel plate (S235JR steel) with possible application as replacing material for reservoirs and chute. Schematic drawing with typical proportion of base materials and wear resistant layers, typical microstructure and chemical composition are shown respectively on Figs 1-2 and Table 1.

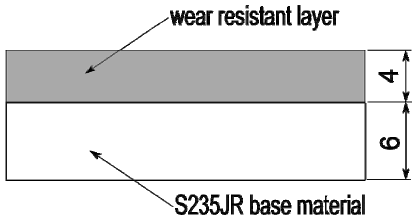


Fig. 1. Wear plate system diagram

Table 1.
Wear resistant layer chemical composition

Chemical composition, wt [%]				
C	Cr	Nb	B	Fe
5.2	22	7	1.8	bal.

The basic chemical compounds present in the tested wear plate are: chromium, niobium and boron which assure hypereutectic matrix. The concentration of chromium carbides is higher than 45%. Average hardness of wear resistant plate is 68 HRC (matrix hardness is about 850 HV30, carbides - 1500 to 3000 HV). Max. work temperature is up to 250°C. Base material is the constructional steel of S235JR grade.

2.1. Welding procedure

The analysis of structure and properties was carried out on experimental joint MAG welded with 1.2 mm G3Si1 solid wire and Arcal 21 (92% Ar + 8% CO_2) shielding gas, Fig. 3 presents preparation for welding and operational sequence scheme, Table 3 welding parameters.

a) b)

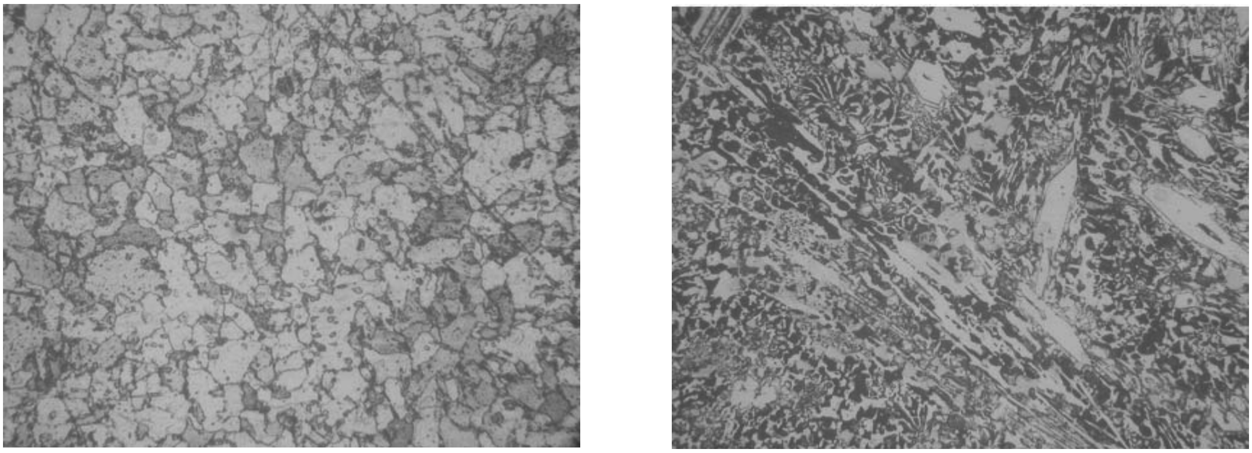


Fig. 2. Microstructure of wear plate system: a) base material: ferrite-perlit, b) wear resistant layer: chromium cast iron

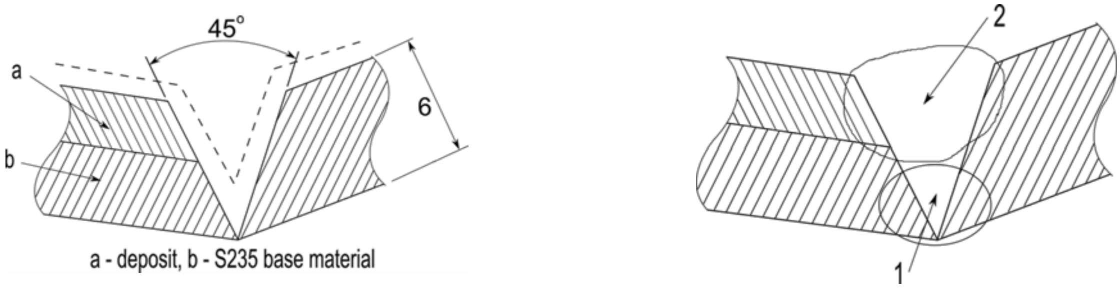


Fig. 3. Diagrams of preparation for welding and operational sequence

Table 2.
Wear plate - constructional steel plate experimental joint welding parameters

Bead number	Welding method	Wire diameter [mm]	Welding current I [A]	Arc voltage U [V]	Welding polarity	Wire feeding speed [m/min]	Welding speed [cm/min]
1	135	ø1.2	200	21.5	DC +	0.4-0.6	90-100
2			200	22.5		0.4-0.6	50-60

3. Metallographic examinations

Quality of tested joint was assessed based on visual examination according to PN-EN 970 standard and penetrant testing PT according to PN-EN 571-1. Results of these tests indicate that root of weld was free from any cracks however some cracks appeared on the weld face, Figs 4 and 5.

Microstructure changes in the weld were defined during macro- and microscopic examinations. Results of these examinations were show in Fig. 6.

Macroscopic examinations of cross sections corresponds with penetrant testing results confirming presence of cracks in the face weld and their absence in the root weld. The source of the crack is due to the mismatch of materials properties, namely in the interface between filler metal and wear resistant plate material.

Changes of chemical composition induce hardening of this area during cooling resulting in martensitic structure. Additionally one can see microstructure changes in the area of heat affected zone HAZ from initial ferrite pearlite structure typical for base material thru grain growth to bainite structure. Bainite structure is present also in the middle area of weld. Root of the weld has ferrite-pearlite structure. Microanalysis of chemical composition EDS confirms that in weld area because of non uniform chemical composition of the welded joint there are passage of different microstructures. There are significant changes in the carbon concentration as well as alloying elements taking part in microstructure formation. Most of important changes during welding of wear resistant material are connected with melting, mixing and carbides passage into weld area. Inhomogeneous intermix of wear resistant layer with filler materials is observed, Fig. 7 with clearly visible niobium carbides and chromium carbides eutectic mixtures, Fig. 8. Because of limited time there are no big dissolution of alloying carbides in that transition areas.

4. Hardness tests

To define properties of weld and HAZ, hardness tests were carried out. Hardness was measured using the hardness tester with 9,81 N load with the time duration of 15 seconds. The schematics of experimental set-up and results were shown in Fig. 9 and Table 3.

Results of hardness measurements indicate differences in the hardness of the particular zones of investigated weld. Those results corresponds with microstructure observations. The lowest hardness c.a. 120 HV was measured for base material, the highest c.a. 800 HV for surface layer of wear plate. Additionally as expected the biggest scatter of measured results was observed for HAZ and interface of wear resistant layer and face weld. Also weld face present difference in the measured hardness.

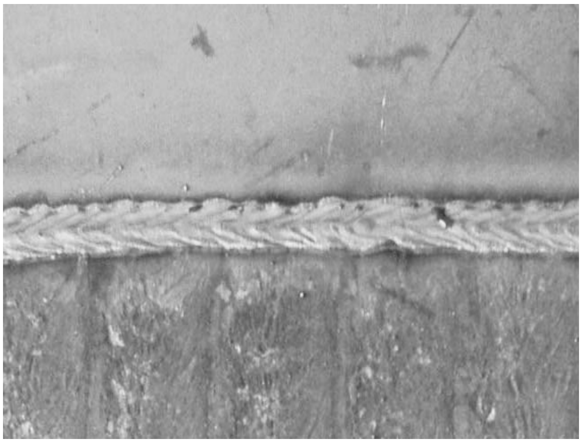
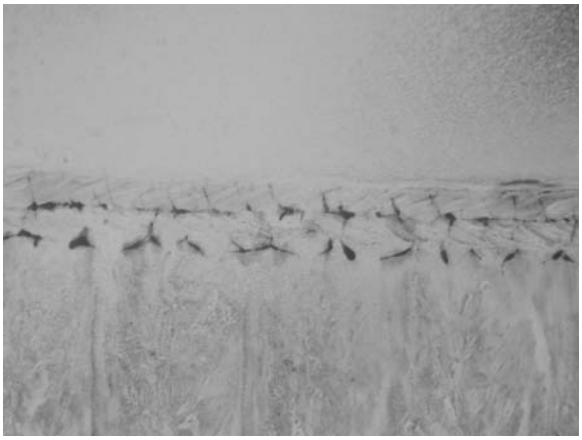



Fig. 4. Macroscopic view of the face of the weld before and after PT examination

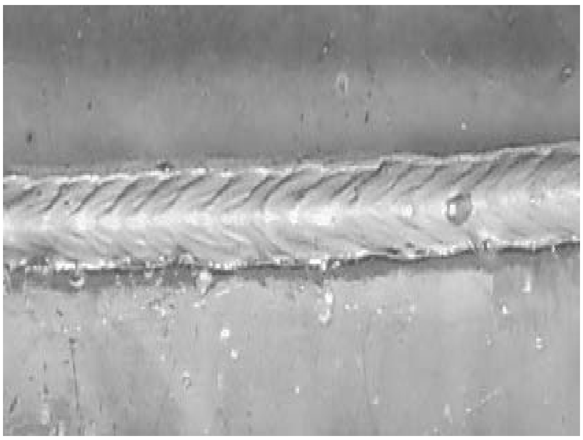
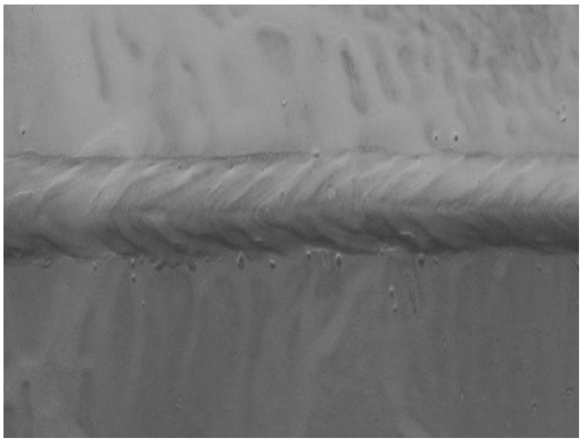
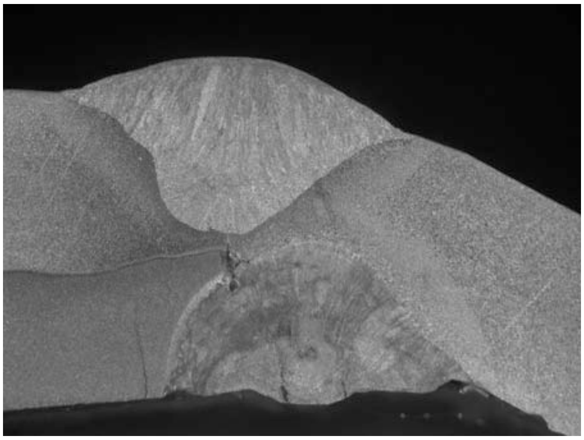
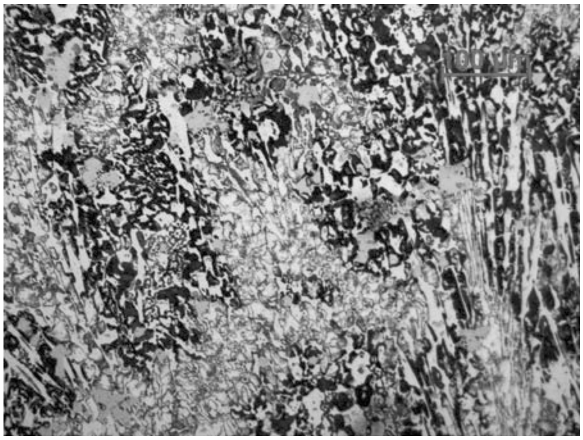



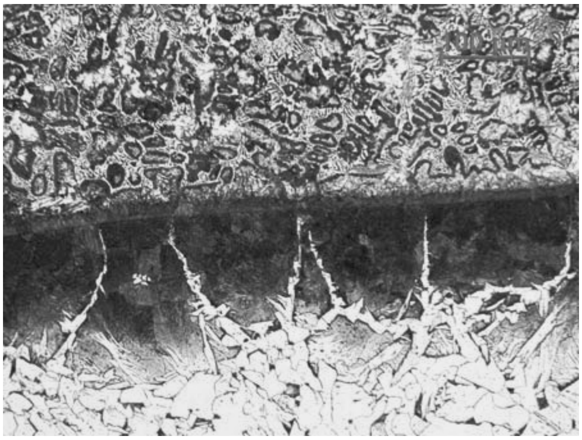
Fig. 5. Macroscopic view of the root of the weld before and after PT examination



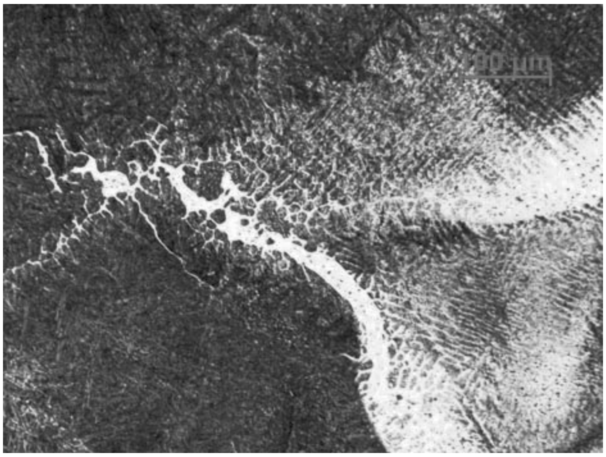
Macrographs of wear plate – constructional steel welded joint, etching: Adler, 4x



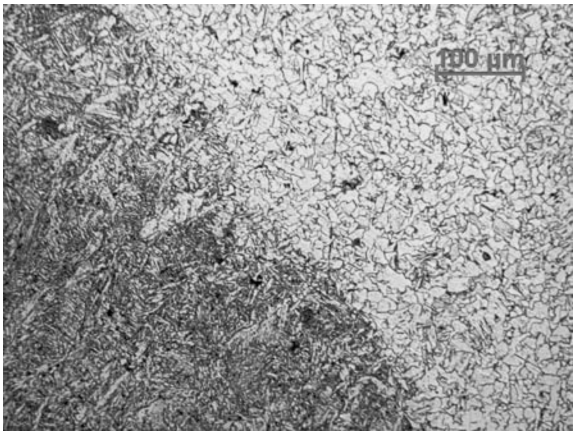
Carbides precipitations in wear resistant layer



Area between wear resistant layer and constructional steel



Intermix of wear resistant layer material with filler material



Area between weld and HAZ (from constructional steel side)

Area between weld number 2 and constructional steel

Fig. 6. Microstructures of wear plate - constructional steel welded joint

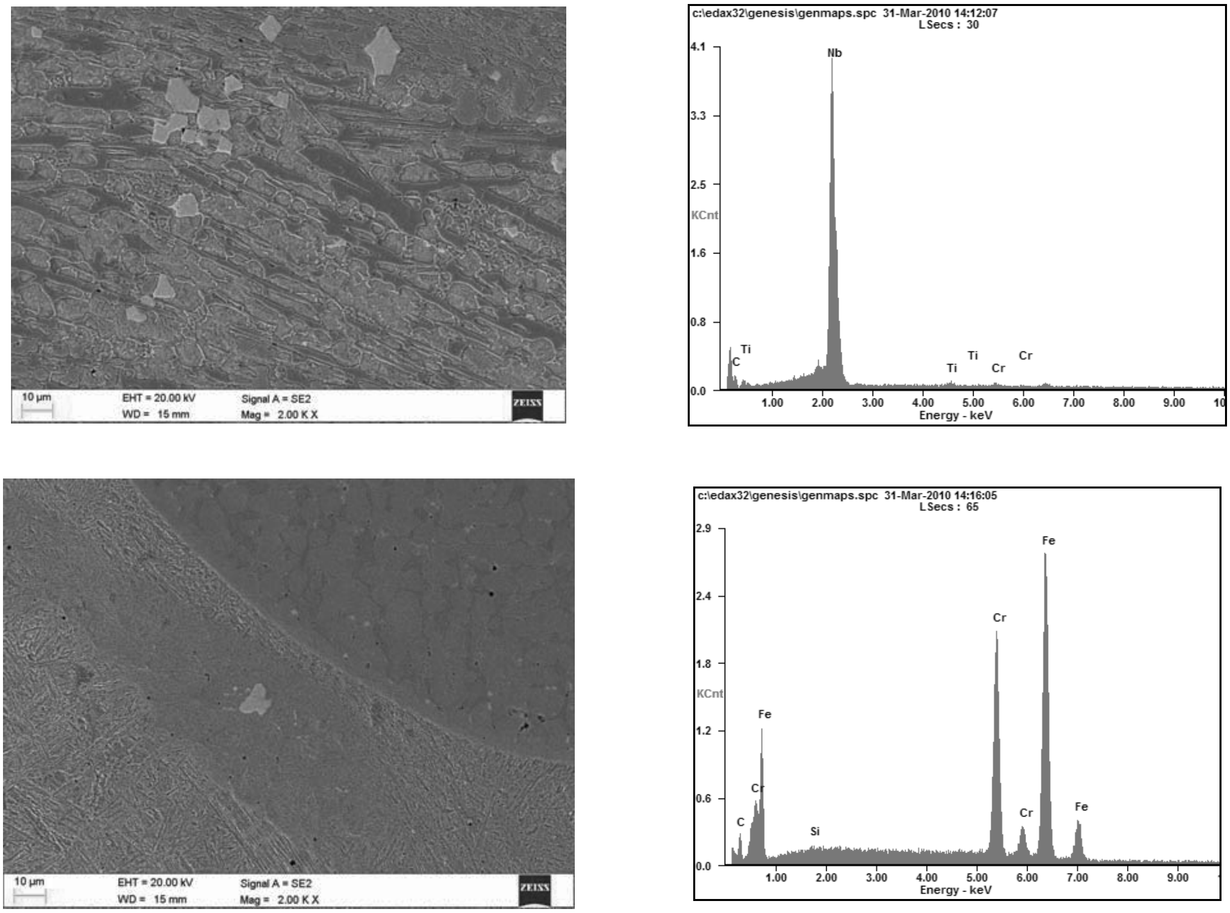
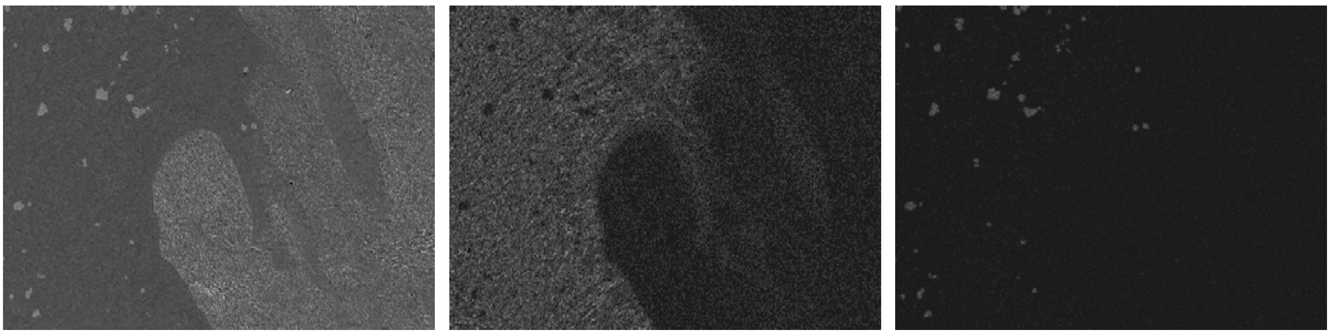


Fig. 7. Results of EDS microanalysis of wear resistant plate-constructional steel welded joints - SEM images with EDS spectra respectively for niobium carbides and chromium carbides mixture



A view of intermix area | Chromium distribution | Niobium distribution

Fig. 8. The surface distribution of alloying components in weld area

Table 3.
Hardness test results for the wear plate - constructional steel welds

Measurement point	1	2	3	4	5	6	16	17	18	19
	Base plate			Surface layer of wear plate			HAZ of wear plate base material		HAZ of wear plate deposit	
HV1	116	119	121	797	784	820	146	127	860	580

Measurement point	7	8	9	10	11	12	13	14	15
	Weld root		Central weld				Weld face		
HV1	203	202	194	298	294	286	447	588	554

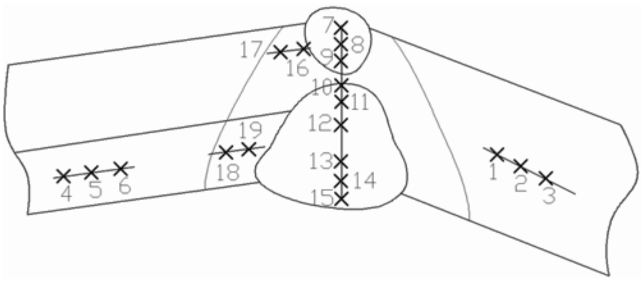


Fig. 9. Hardness measurement points on the cross-section of welded joint

5. Conclusions

Based on the experiment results presented in this report following conclusions are possible to draw:

- welding of wear resistant plate with constructional steel is possible, but special attention is needed during the welding process of the root,
- root weld must be free of cracks and possibly free of intermixing with wear resistant plate material,
- applying welding parameters described in the paper is possible to achieve free of cracks root,
- presence of crack in face weld is not important in term of wear resistance abilities of chute,
- most of important changes during welding of wear resistant material are connected with melting, mixing and carbides passage into weld area,
- non uniform chemical composition of the welded joint creates different microstructures with different hardness.

References

[1] K. Kato, Abrasive wear of metals, Tribology International 5 (1997) 333-338.

[2] K.H. Zum Gahr, Wear by hard particles, Tribology International 31/10 (1998) 587-596.

[3] J.A. Francis, B. Bednarz, J.V. Bee, Prediction of steady state dilution in multipass hardfacing overlays deposited by self shielded FCAW, Science and Technology of Welding & Joining 7/2 (2002) 95-101.

[4] D.A. Stewart, P.H. Shipway, D.G. McCartney, Influence of heat treatment on the abrasive wear behaviour of HVOF sprayed WC-Co coatings, Surface and Coatings Technology 105/1 (1998) 13-24.

[5] Castolin Eutectic, Catalogue. CastoDur Diamond Plates. CastoTubes.

[6] S.G. Sapate, A.V. Rama Rao, Effect of carbide volume fraction on erosive wear behaviour of hardfacing cast irons, Wear 256/7-8 (2004) 774-786.

[7] A.N.J. Stevenson, I.M. Hutchings, Wear of hardfacing white cast irons by solid particle erosion, Wear 186-187/1 (1995) 150-158.

[8] T. Kasuya, Y. Hashiba, S. Ohkita, M. Fuji, Hydrogen distribution in multipass submerged arc weld metals, Science and Technology of Welding & Joining 6/4 (2001) 261-266.

[9] Q. Wei, F. Hu, D.J. GUO, A study of weld pore sensitivity of self-shielded, flux cored electrodes, Welding Journal 81/6 (2002) 90-94.

[10] S. Babu, S.A. David, M. Quintana, Modeling microstructure development in self-shielded flux cored arc welds, Welding Journal 80/4 (2001) 91-97.

[11] Manufacturer Says New Wear Plate is Hard, Tough and Work-Friendly, Engineering & Mining Journal 206/3 (2005).

[12] P. Hansson, C. Lowgren, Properties of Modern Wear Resistant Steels, Svetsen, 1990.

[13] E. Fundal, Abrassive wear mapping using the micro wear test, Conference Nortrib'92, Tribology, 11/3 (1992).

[14] Marujan Heave Industrie to Import Swedish Abrassion - Resistant Steel, New Materials, Japan, 1992.

[15] A. Klimpel, J. Górka, A. Czupryński, Comparison of chromium cast iron deposits of wear plates, Journal of Achievements in Materials and Manufacturing Engineering 18 (2006) 387-390.

[16] A. Klimpel, J. Górka, Properties of chromium cast iron deposits SSA surfaced, The14th International Scientific Conference on "Achievements in Mechanical and Materials Engineering AMME'2006, Gliwice-Wisła, 2006.