METABK 59(4) 470-472 (2020)
UDC – UDK 669.182:621.791.053/66.065:620.178.1:546.78-661:111

UTILIZATION OF DIFFRACTION ANALYSIS IN THE STUDY OF MARTENSITIC WELD DEPOSITS USING TUNGSTEN CARBIDE PARTICLES ON S235JR+N STEEL

Received – Primljeno: 2020-01-09
Accepted – Prihvaćeno: 2020-06-10
Original Scientific Paper – Izvorni znanstveni rad

The durability of classic structural steels against various types of wear is generally low. Therefore, various types and combinations of resilient materials are constantly evolving, which are designed to reduce the cost of components replacement or repairs. This paper deals with the structures that are formed in a weld after addition of tungsten carbide particles to protect the surface of the components from wear. The resistance of the weld surface layer containing tungsten carbides is also evaluated in comparison with a layer without these particles.

Key words: steel S235JR+N, weld deposit, abrasion, tungsten carbide, martensitic matrix

INTRODUCTION

Abrasion is one of the most common causes for which it is necessary to replace or repair all sorts of parts in machines. These machines usually work in quarries, mines, agriculture, construction industry and other similar areas. There is strong wear on the parts, which include the teeth of the dredgers, conveyor screws, drills etc. This wear causes massive material loss and deterioration of these work parts. Thanks to the welding or thermal spraying, however, it is possible to renovate these tools. This leads to a significant reduction in the costs of companies using these machines [1 - 3].

Nowadays, there is a wide range of welding technologies and, of course, materials that we can use for these weld deposits. This research focuses on the use of tungsten carbide particles (WC) located in a martensitic matrix on the bases of iron.

The research was carried out on 2 samples, differing with the presence of WC particles in the weld matrix [4 - 6].

MATERIALS AND METHODS

For the experiment, tungsten carbide was used supplied by the manufacturer Durum, namely the Durmat FTC (Fused Tungsten Carbide). It consists of phases of WC and W_2C. The average carbon content varies between 3,8 and 4,1 %. The phase ratio is then 78 - 80 % W_2C to 20 - 22 % WC. This 1 - 2 mm particle size powder is intended primarily for use in weld deposits. For the experiment, the basic material S235JR+N was used Table 1.

Table 1 **Chemical composition of S235JR+N / mas. %**

C	Si	Mn	P	S
0,14	0,20	0,67	0,01	0,02
Cr	Ni	Cu	Al	Fe
0,02	0,01	0,01	0,05	rest

Table 2 **Chemical composition of Megafil A864M / mas. %**

C	Si	Mn	P	S
0,426	0,27	1,05	0,025	0,025
Cr	Ni	B	Fe	
0,27	1,57	4,62	rest	

As a filler material, Megafil A864M was chosen in the form of a filled electrode with a diameter of 1,6 mm, Table 2. This material is used in common practice to weld layers to products exposed to various types of material wear in the extractive and mining industries. The welding metal contains a martensitic structure with the hardness of 62 - 67 HRC. A gas mixture was used as a shielding gas with 82 % of Ar and 18 % of CO_2. The WC17 sample was welded only by Megafil A864M, for the WC15 sample Durmat FTC tungsten carbide particles were added (see above). Experiment is a part of bigger comparison with different parameters [7]. Welding parameters are shown in Table 3.

Table 3 **Welding parameters**

	WC17	WC15
Current / A	260	250
Voltage / V	32	29
Speed / $mm.s^{-1}$	5 - 6	4 - 5

J. Kozák, jindrich.kozak@vsb.cz, L. Krejčí, lucie.krejci@vsb.cz, I. Hlavatý, ivo.hlavaty@vsb.cz, R. Čep, robert.cep@vsb.cz, Faculty of Mechanical Engineering VSB-TU Ostrava, Czech Republic.
I. Samardžić, ivansamrd@gmail.com, Faculty of Mechanical Engineering Slavonski Brod, Croatia.

X-ray diffraction (XRD) analysis

The XRD analysis of the phases in the welds was done using the PANalytical Empyrean apparatus. In this way, a phase analysis was carried out during the welding in the individual samples of the weld.

Chemical analysis of weld deposits

The chemical analysis was carried out using the electron microscope TESCAN 5130SB. Linear chemical analysis was done in selected areas between the weld and the base material. The surface chemical analysis has always been made in the matrix of the weld, 0,5 mm from the weld surface, 0,5 mm above the melting limit and, further, 0,5 mm below the melting limit in the base material.

Abrasive wear test

Dry Sand/Rubber Wheel Abrasion Testing Device was used to measure abrasive wear, corresponding to the standard ASTM G 65. The measurement was carried out on samples with a pre-ground weld surface. Rotational speed corresponded to 60 revolutions per minute, using 5kg weights to create a downforce thanks to the leverage 23 N acting perpendicular to the surface of the wheel with rubber surface. Abrasive (sand of granularity 0,1 - 0,6 mm) was dosed in the amount of 27 - 32 g per minute. The measurement was divided into 5 periods after 12 minutes. At the end of each period, the weight loss of the sample was measured. Subsequently, the weld surface was observed to evaluate the wear using an Scan electron microscope [8 - 9].

RESULTS AND DISCUSSION

XRD analysis

On Figures 1 and 2 is shown an analysis of the phases carried out, focusing on phases occurring during welding on individual weld samples.

The WC17 sample shows only the formation of iron alpha in the weld of iron boride Fe2B (see Figure 1).

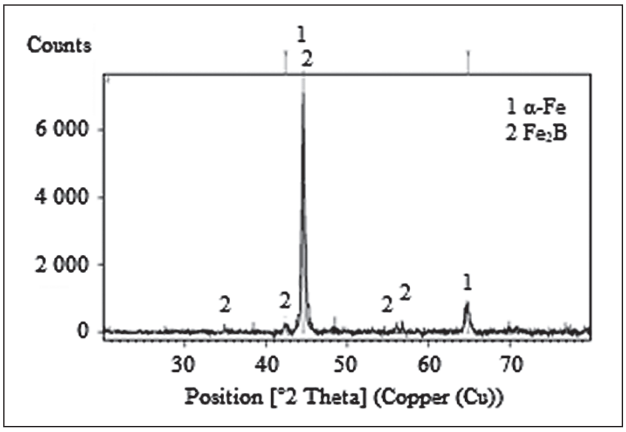

Figure 1 XRD analysis of the WC17

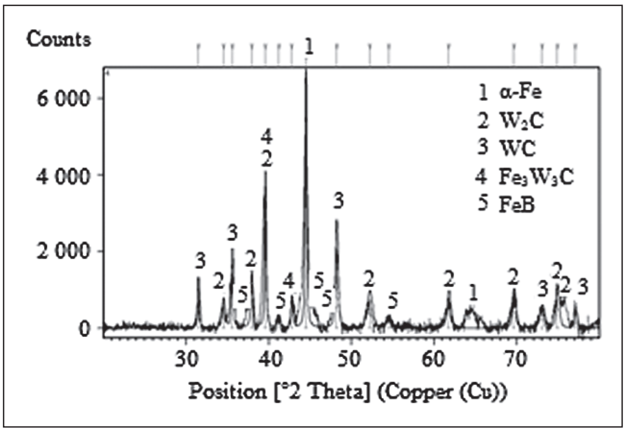

Figure 2 XRD analysis of the WC15

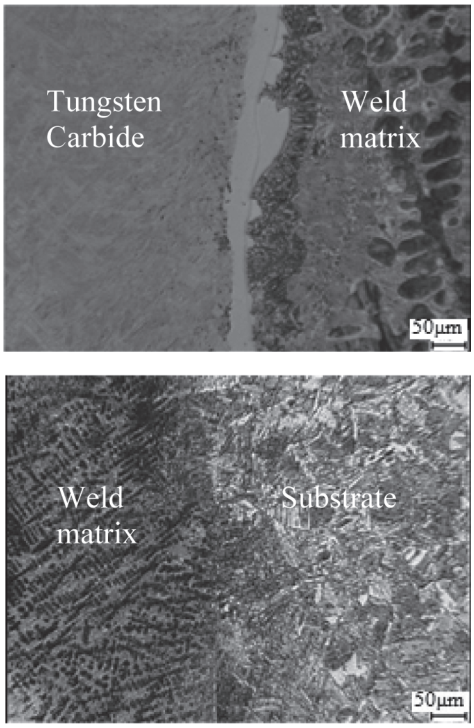

Figure 3 The microstructure of the sample WC15

Likewise, in the sample WC15 (see Figure 2), the iron alpha phase was formed. Also, both forms of tungsten carbide WC and W2C were present, together with boride iron FeB and mixed tungsten carbide and iron Fe3W3C. In Figure 3, it can see an example of a microstructure in the weld matrix and the base material.

Chemical analysis of weld deposits

Figure 4 and Table 4 represent the distribution of elements in the weld matrix, tungsten carbide particle and

Table 4 **Chemical composition in selected areas of the WC15 (1 – Surface, 2 – Interface, 3 – Heat Affected Zone (HAZ)**

Place	Si	Cr	Mn	Fe	Ni	W
1	0,50	0,32	0,83	93,52	0,77	4,05
2	0,31	0,40	0,19	92,96	0,76	5,38
3	0,46	0,21	0,78	98,56	0,00	0,00

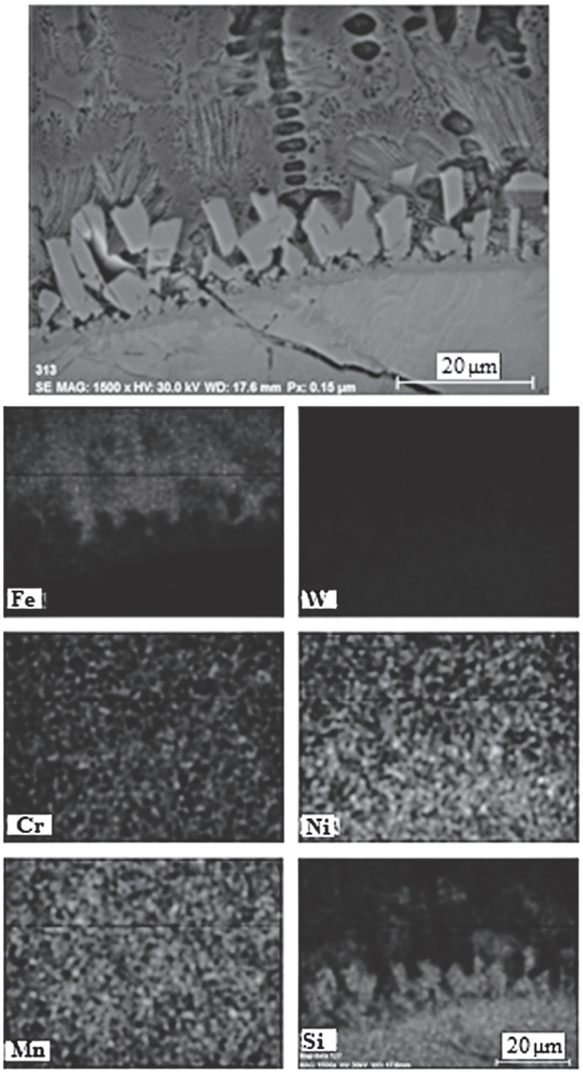

Figure 4 Course of the chemical composition of WC15

substrate heat affected zone (HAZ). Some coherence of silicon with tungsten can be observed.

Abrasive wear test

From the graph on Figure 5 one can observed that the tungsten carbide particles have a significant influence on the abrasion resistance of the weld. Weight loss in the sample WC17 was 0,728 g over 0,403 g in the case of the WC15 sample.

CONCLUSION

The XRD analysis of the welds has shown that the weld containing tungsten carbide particles occur, in addition to the standard structures (iron alfa, iron borides), also mixed tungsten carbide and iron Fe_3W_3C. This compound carbide is produced by melting the tungsten carbide particles and mixing this melt with the weld matrix. The chemical analysis showed the approximate distribution of selected chemical elements at the boundaries of tungsten carbide particles and the matrix of the weld.

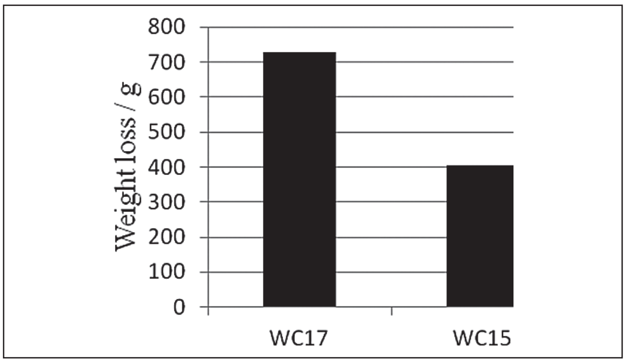

Figure 5 Comparison of sample weight loss after the abrasion test

A significant part of the experiment was also a comparison of the weld resistance to abrasive wear. Once again, the weld with tungsten carbide particles was compared with the weld that did not contain these particles. The result unequivocally confirmed the usefulness of tungsten carbide particles and their importance in increasing the lifespan of components exposed to abrasive wear during their service life.

LITERATURE

[1] B. Vamsi Krishna, V. N. Misra, P. S. Mukherjee, P. Sharma, Microstructure and properties of flame sprayed tungsten carbide coatings, International Journal of Refractory Metals & Hard Materials 20 (2002), 355-374.

[2] C. Verdon, A. Karimi, J.-L. Martin, A study of high velocity oxy-fuel thermally sprayed tungsten carbide-based coatings, Part 1: Microstructures, Materials Science and Engineering 246 (1998), 11-24.

[3] E. Badisch, M. Kirchgaßner, Influence of welding parameters on microstructure and wear behaviour of a typical NiCrBSi hardfacing alloy reinforced with tungsten carbide, Surface & Coatings Technology 202 (2008), 6016-6022.

[4] Z. Yao, J. J. Stiglich, T. S. Sudarshan, Nano-grained tungsten carbide-cobalt (WC/Co), Materials Modification, Inc. [online]. (2012), http://www.matmod.com/publications/armor_1.pdf.

[5] B. Venkatesh, K. Sriker, V. Prabhakar, Wear characteristics of hardfacing alloys: state-of-the-art. Procedia Materials Science 10 (2015), 527-532.

[6] Z. Kamdi, P. H. Shipway, K. T. Voisey, A. J. Sturgeon, Abrasive wear behaviour of conventional and large-particle tungsten carbide-based cermet coatings as a function of abrasive size and type, Wear 271 (2011), 1264-1272.

[7] I. Hlavatý, J. Kozák, L. Krejčí, I. Samardzic, J. Tuominen, The effect of tungsten carbide particles content in a weld deposit on its abrasion resistance, Technical Gazette 24 (2017), 1345-1349.

[8] D. M. Kennedy, M. S. J. Hashmi, Methods of wear testing for advanced surface coatings and bulk materials. Journal of Materials Processing Technology 77 (1998), 246-253.

[9] M. Kašparová, F. Zahálka, Š. Houdková, Evaluation of abrasive and adhesive resistance of materials. Metal Conference (2009), 1-7.

Note: Responsible translator: Mgr. Andrea Wlochová, Ph.D., head of Department of Languages VSB-TU Ostrava