PHASE EVALUATION OF FEBNICR WELD DEPOSIT WITH ADDED TUNGSTEN CARBIDE PARTICLES

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Abstract

Hard particles used in combination with iron-based matrix are applied in a wide range of areas. It is used for screw conveyors, de-baler knives or mining gear teeth. The weld deposits can be used both in the production of these machine parts and in their later repair to increase their service life. The paper deals with the analysis of microstructures produced in the weld deposits combining martensitic matrix and 1-2 mm tungsten carbide particles. The investigated weld deposit was performed by welding technology using filled electrode Megafil A864M in a mixed gas atmosphere (Ar + N). Tungsten carbide particles were added due the vibratory feeder. Steel S690QL was used as a parent material.

The research focuses mainly on the microstructure analysis by electron microscopy (SEM) and the investigation of individual phases by diffraction analysis XRD. Using point chemical analysis, the movement of individual chemical elements between the base material, the weld deposit and the tungsten carbide particles was examined. Part of this paper is focused also on SEM investigation of worn surface of the weld deposit.

Keywords: Tungsten, carbide, hard-facing, microstructure, weld deposit

1. INTRODUCTION

Wear of parts during its operation live have a negative effect on their function. At the moment, there are many ways of renovation to extend the service life of individual parts and to reduce the cost of replacing them. Weld deposit is one of the methods of repairing not only worn parts but also for enhancing extremely stressed parts already in the production process. One of the applications includes tools (cylinders, machining tools, screw conveyors, knives, mining teeth, etc.) used for the treatment of soils, rocks, metals and wood. These parts have to meet the high demands on their service life, productivity and safety. It must withstand temperatures, shocks, wear, etc. In case of wear, it must fulfill the condition of sufficient hardness and surface resistance. On the other hand, tool cracks must not occur during vibrations or sudden shocks in operation mode [1,2,3].

2. EXPERIMENT

Megafil A864M in the form of a 1.6 mm diameter filled electrode (for chemical composition, see **Table 1**) was used. This material is commonly used for weld deposits of products exposed to various types of material wear in mining industries. The weld metal has a martensitic structure with a hardness of 62-67 HRC. The samples were deposited in the protective atmosphere of 50 % Ar and 50 % N_2. This gas has been chosen because of the possibility of boron nitrides in the weld deposit and possible influence on the resulting properties of the weld deposit. As the parent material steel S690QL (for chemical composition, see **Table 2**) was used.

Table 1 Chemical composition of filler metal Megafil A864M

C	Si	Mn	P	S
0.426	0.270	1.050	0.025	0.025
Cr	**Ni**	**B**	**Fe**	
0.270	1.570	4.620	rest	

WC07 sample was welded without any tungsten carbide particles. For sample WC05, tungsten carbide particles of about 1-2 mm in diameter were added to the molten pool during hard-facing. The welding parameters are shown in the **Table 3**.

Table 2 Chemical composition of parent material (substrate) S690QL

C	Mn	Si	S	P	Cr	Ni	Cu
0.20	1.70	0.80	0.01	0.01	1.50	2.00	0.50
Ti	B	As	N	Mo	V	Nb	Fe
0.05	0.005	0.70	0.015	0.001	0.12	0.06	rest

Table 3 Welding parameters

	WC07	**WC05**
Welding current	260 A	250 A
Welding voltage	33 V	27 V
Welding speed	5-6 $mm \cdot s^{-1}$	4-5 $mm \cdot s^{-1}$
Gas flow	18 $l \cdot min^{-1}$	18 $l \cdot min^{-1}$
WC particles (size)	No	Yes (≈1-2mm)

3. RESULTS

3.1. Xrd difraction analysis

WC07 samples produced α-Fe, chromium boride CrB_4, carbon nitride C_3N_4. Probably there is also iron nitride $Fe_3N_{1.22}$ and boron nitride BN (see **Figure 1**).

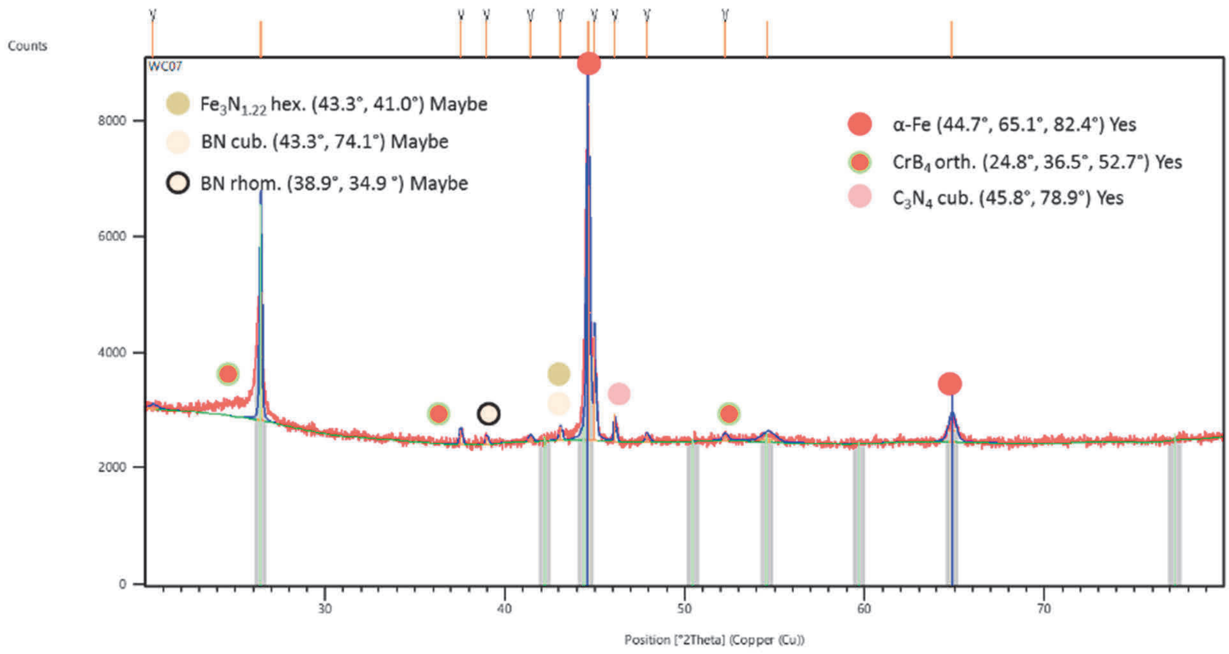

Figure 1 Xrd difraction analysis of WC07

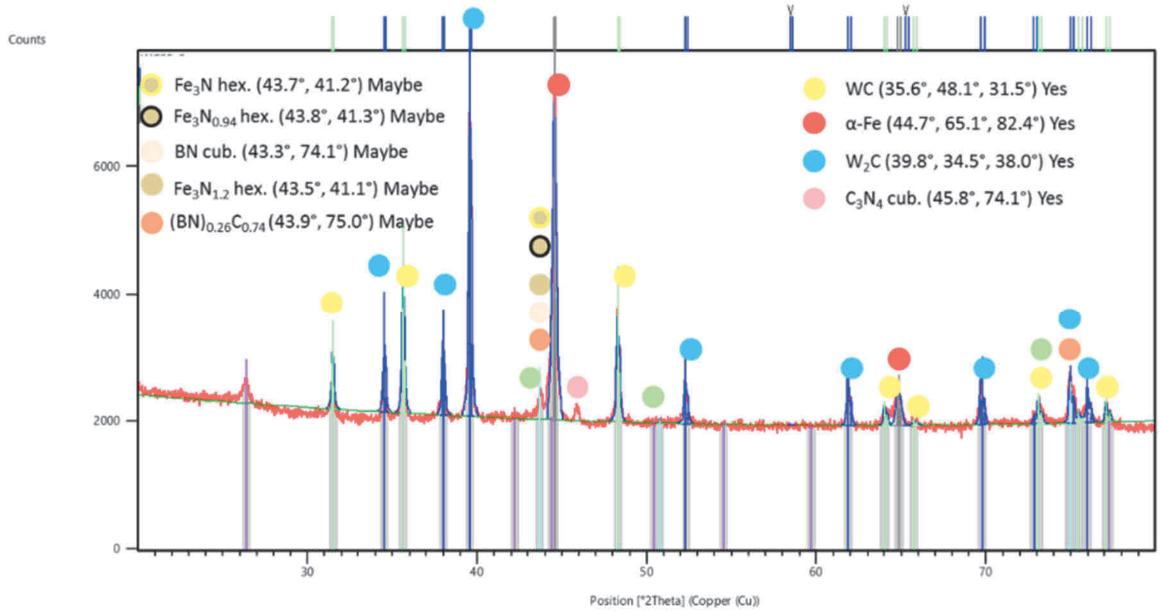

Figure 2 Xrd difraction analysis of WC05

The WC05 sample (see **Figure 2**) shows α-Fe, both forms of tungsten carbide WC and W_2C and carbon nitride C_3N_4. Furthermore, there is a high probability of occurrence of iron nitrides Fe_3N and $Fe_3N_{0.94}$ and $Fe_3N_{1.2}$, boron nitride BN and boron carbonite $(BN)_{0.26}C_{0.74}$.

3.2. Chemical analysis by SEM

Table 4 Chemical analysis of both samples

WC07						
	Si	**Cr**	**Mn**	**Fe**	**Ni**	**W**
Weld deposit - surface	0.49	0.51	0.59	97.54	0.87	-
Weld deposit - melting boundary	0.50	0.55	0.62	97.51	0.83	-
Substrate - HAZ	0.56	0.75	0.88	97.66	0.15	-

WC05						
	Si	**Cr**	**Mn**	**Fe**	**Ni**	**W**
Weld deposit - surface	0.43	0.61	0.38	90.45	0.80	7.34
Weld deposit - melting boundary	0.38	0.57	0.48	87.98	0.95	9.63
Substrate - HAZ	0.51	0.78	0.91	97.63	0.17	0.00

In case of WC07 measured elements (silicon, manganese, chromium and nickel) show a steady state in the direction from the weld deposit to the parent material within the measured range. **Table 4** shows the amount of the chemical elements in each region in a wider range.

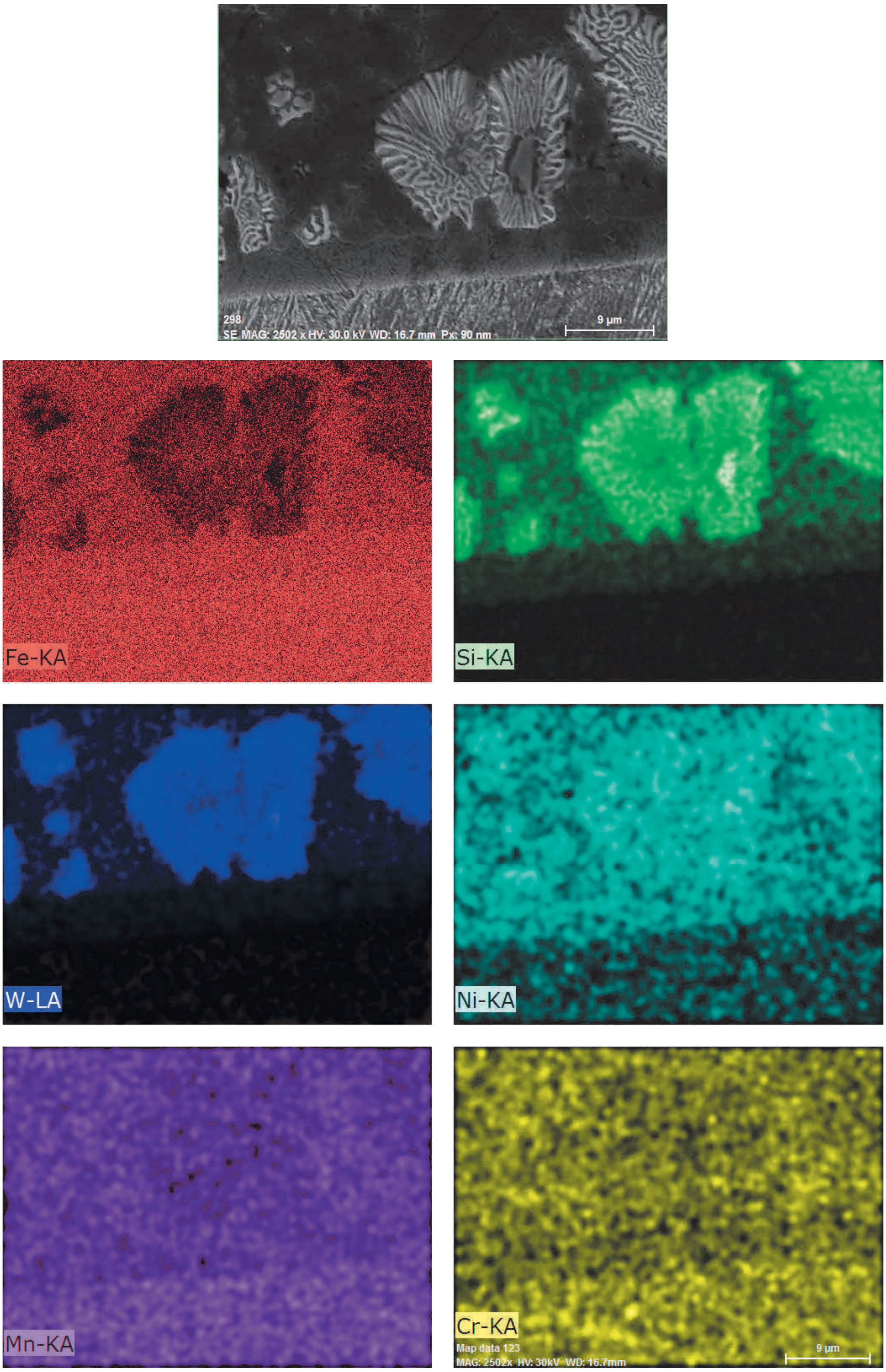

Figure 3 Mapping of chemical elements in the microstructure of weld deposit of WC05

For sample WC05, amount of tungsten and silicon decreases in direction out of the tungsten carbide particles (see **Figure 3**). At the same time, the iron content of the matrix increases sharply, which then continues into the heat-affected area of the parent material.

3.3. Abrasion test

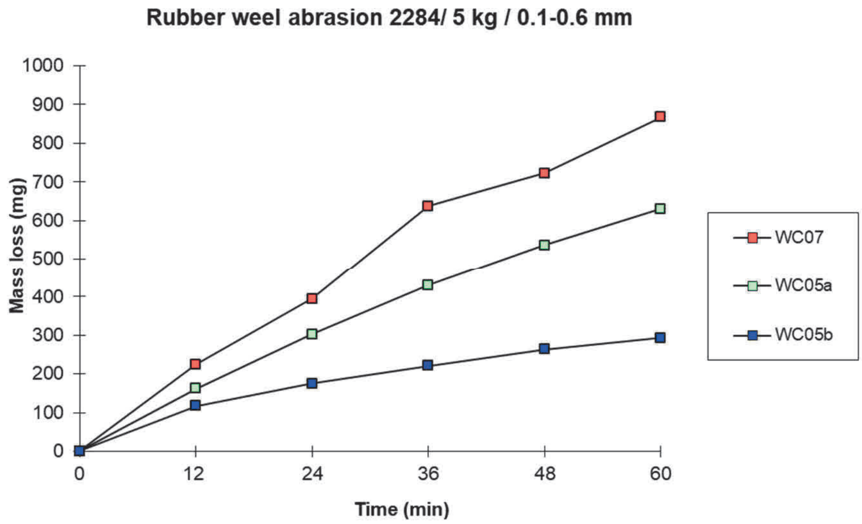

Figure 4 Mass loss of both samples after abrasion test

Table 5 Mass loss of both samples during abrasion test

Mass of samples (g)							Mass loss (g)
Sample	**0 min**	**12 min**	**24 min**	**36 min**	**48 min**	**60 min**	
WC07	170.367	170.142	169.972	169.730	169.644	169.500	0.867
WC05a	194.788	194.626	194.485	194.358	194.252	194.157	0.631
WC05b	180.699	180.582	180.524	180.478	180.435	180.406	0.293

After abrasion test using rubber wheel you can see in **Table 5** and **Figure 4**, the sample WC05 containing tungsten carbide particles (0.631/0.293 g weight loss) has higher abrasion resistance compared to WC07 with a weight loss of 0.867 g. Subsequently, a study of the worn surface of the weld deposits was carried out using SEM to determine the mechanism of wear of the wear.

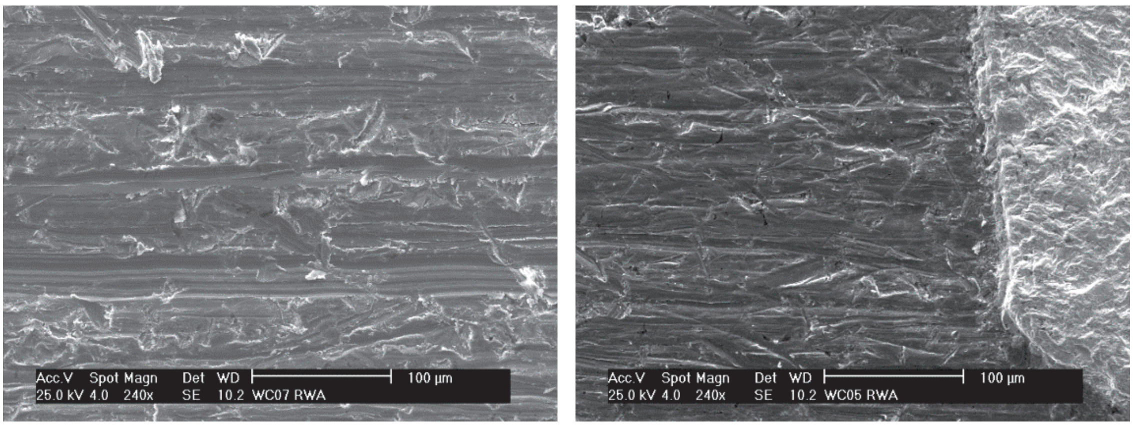

Figure 5 SEM analysis of the worn surface of both samples

The surface of the sample WC07 shows sharp edges, that have been formed by cutting the material with abrasive and occur continuously throughout the surface. There are no tungsten carbide particles that would stop the abrasive particles and prevent motion. In addition, a number of scratches can be observed on the surface, resulting in the puncture of the material after impact of the abrasive on the surface (see **Figure 5**).

At WC05 sample, abrasive paths created by cutting are observed when moving on the surface of the weld deposit (see **Figure 5**). However, there is an impact on tungsten carbide particles, which bounce them away from the surface, preventing them from continuing on the surface and its degradation. The gaps occur in different directions, formed after the abrasive particles are bounced off the tungsten carbide particle.

A simulation experiment in an abrasive environment was performed on WC05. After depositing the WC05 sample, the area fraction of the tungsten carbide particles to the matrix was only 7 - 8 %, which had a negative influence on the weight loss of the weld deposit during abrasion (WC05a sample in **Table 5**). The reason for this was the drop of particles towards the melting boundary during welding due to their higher density. The experiment consisted of removing a 1.5 mm layer from the weld deposit, which revealed a higher amount of tungsten carbide particles on the surface. Their area fraction increased to 24 - 25 % of the surface (WC05b sample), resulting in increased abrasion resistance (see **Table 5**) [4,5].

4. CONCLUSION

The main conclusion we can see in following points:

- Direct positive influence of presence and volume fraction of tungsten carbide particles in the weld deposit on its abrasion resistance.
- Study of phases and structures produced in the weld deposits combining tungsten carbide particles with the matrix with an increased content of boron using protective atmosphere of a mixture gas of argon and nitrogen resulting in appearance of boron nitrides or carbonitrides.
- Performance of an area chemical analyzes describing layout of chemical elements in the structure of weld deposits.

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REFERENCES

[1] HLAVATÝ, I., KOZÁK, J., KREJČÍ, L., SAMARDŽIČ, I. and TUOMINEN, J., The effect of tungsten carbide particles content in weld deposit on its abrasion resistence. *Tehnicki Vjesnik-Technical Gazette*, vol. 24, 2017, ISSN 1330-3651

[2] LOU, D., HELLMAN, J., LUHULIMA, D., LIIMATAINEN, J. and LINDROOS, V.K. Interactions between tungsten carbide (WC) particulates and metal matrix in WC-reinforced composites. *Materials Science and Engineering*, vol. 340, 2003, s. 155-162

[3] VAN ACKER, K., VANHOYWEGHEN, D., PERSOONS, R. and VANGRUNDERBEEK, J. Influence of tungsten carbide particle size and distribution on the wear resistence of laser clad WC/Ni coatings. *Wear*, vol. 258, 2005, s. 194-202

[4] JUST, CH., BADISCH, E. and WOSIK, J. Influence of welding current on carbide/matrix interface properties in MMCs. *Journal of Materialls Processing Technology*, vol. 210, 2010, s. 408-414

[5] ZHOU, R., JIANG, Y. and LU, D. The effect of volume fraction of WC particles on erosion resistence of WC reinforced iron matrix surface composites. *Wear*, vol. 255, 2003, s. 134-138