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WEAR BEHAVIOR OF TWO DIFFERENT Cr BASED ALLOYS FOR SURFACING OF STEEL PARTS

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Abstract
In this paper is analyzed wear behavior of two different types of alloys/filler metals aimed for hard surfacing of working parts exposed to intensive abrasive wear and impact loads. The aim of the paper was to determine wear resistance of two different Cr based alloys and possibilities for extending working life of working parts. Base metal, which was surfaced, is steel from group of cheap steels, what have influence on decreasing the manufacturing costs of a new part or revitalization of a damaged one. Surfacing was done by the MMA welding method with use of preheating of the samples. Wear resistance was examined on tribometer by using block-on-disc contact, while the real working conditions were simulated, i.e. contact was realized without lubricating varying the contact speed and loads as input parameters.

1. INTRODUCTION

The objective of this paper is to point to the possibility of prescribing the surfacing technology and select the optimal filler metal for surfacing of parts exposed to intensive wear. The analyzed materials belong to a group of materials aimed primarily for surfacing of parts subjected to abrasive wear. However, in the contact zone frequently appear several wear mechanisms, out of which one could play the dominant role. This is why the objective was to establish which materials are optimal for surfacing of the heavy construction machinery, crusher plants and mills, namely the parts that are being exploited in the conditions of the direct contact with stones and rocks of various hardnesses.
The tested materials are chromium-based alloys characterized by high hardness and wear resistance. The similar materials were the research subject of some of our previous articles where results on surfacing of some other industrial plants parts were

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reported [1-7], as well as of some other authors [8-12]. Tribological characteristics of alloys – the filler metals were determined based on monitoring the wear resistance. The tribological tests were predicting that the investigation – monitoring should be done in conditions without lubrication and for the sliding distance of 300 m.

2. FILLER METALS PROPERTIES

Selection of the filler metals was done based on the purpose of the hard faced parts and based on characteristics that the material must possess. Tested filler metals are aimed to work in extreme wear conditions. In addition, besides wear, very often the impact load is present, which can lead to fatigue of surface layers of working parts. Chosen materials are steel alloys with high carbon and chromium content. The chemical compositions of used metals are given in Tab. 1. Surfacing was done by the MMA welding method in three passes and three layers (Fig. 1a, b, c). Samples were preheated at 300°C and surfacing was done according to parameters given in Tab. 2. Hard faced models are used to cut the blocks for tribological test (Fig. 1d) and metallographic samples – blocks out of them, as shown in Fig. 1c.
Hardness has been measured on surfaces of metallographic samples in different directions necessary to estimate the microstructure of characteristic surfaced zones.

Tab. 1 Chemical composition of the base metal and filler metals [15]

Base metal/Electrodes	Alloying elements [%]							Hardness, HRC
	C	Cr	Mo	W	Mn	Si	N	
S355J0	0.17	-	-	-	1.4	0.55	0.012	≈ 28
E DUR 600 DIN 8555: E 6-UM-60	0.5	7.5	0.5	-	-	-	-	57 - 62
CrWC 600 DIN 8555: E 10-UM-60-C	4.0	26.0	-	4.0	-	-	-	57 - 62

Tab. 2 Hard facing parameters for the MMAW procedure

BM thickness s [mm]	Electrode designation by producer	Electrode core diameter d_e [mm]	Hard facing current I [A]	Voltage U [V]	Hard facing speed v_z, [mm/s]	Driving energy q_l [J/cm]
10	E DUR 600	3.25	120	25	≈ 2.356	11460
	CrWC 600	3.25	125	25	≈ 1.91	14023

3. EXPERIMENTAL INVESTIGATIONS

3.1 Hardness and microstructure

Hardness measurement was done along the three directions perpendicular to the hard faced layers' surface, on samples prepared from the weld metal, according to Fig. 1d). The measurement was done in all the zones of the hard faced layer (weld metal – WM, heat affected zone – HAZ and in the base metal – BM) (Fig. 2). Besides hardness, for every FM, the microstructure was determined. Results are presented as diagrams in Fig. 3.

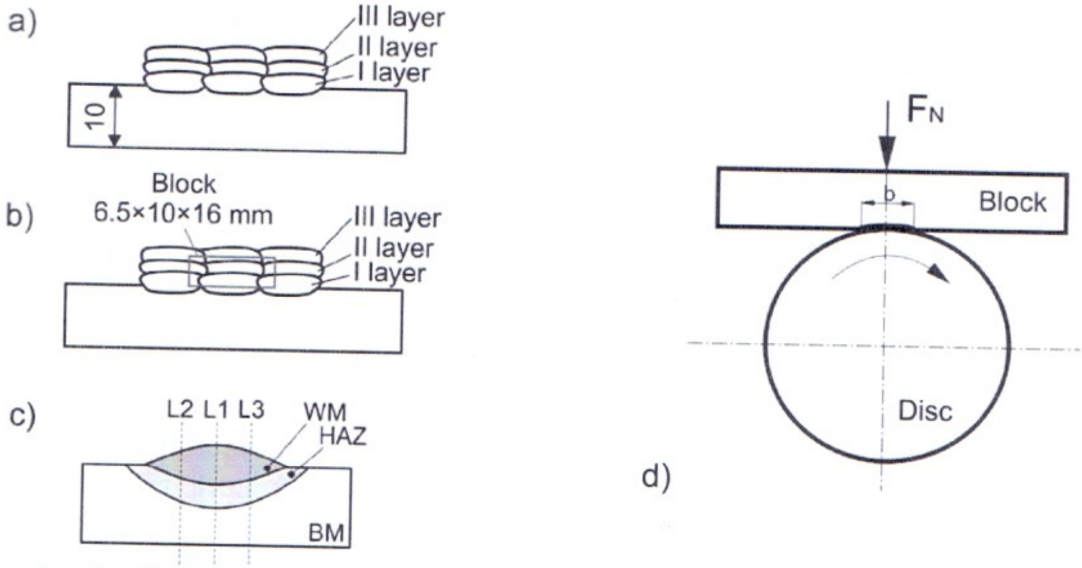


Fig. 1 a, b, c) Order of layers deposition; d) blocks for tribological "block on disk" contact;

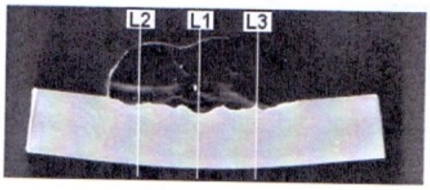
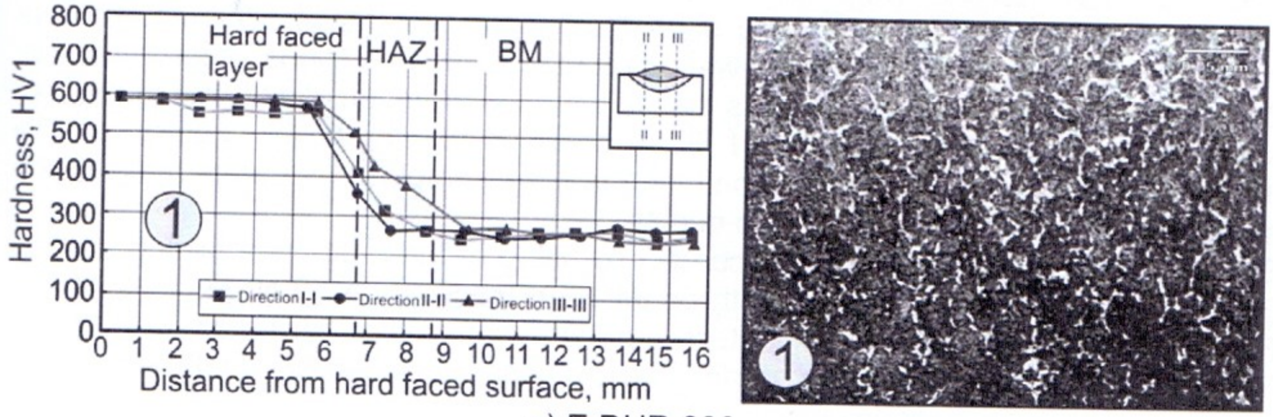
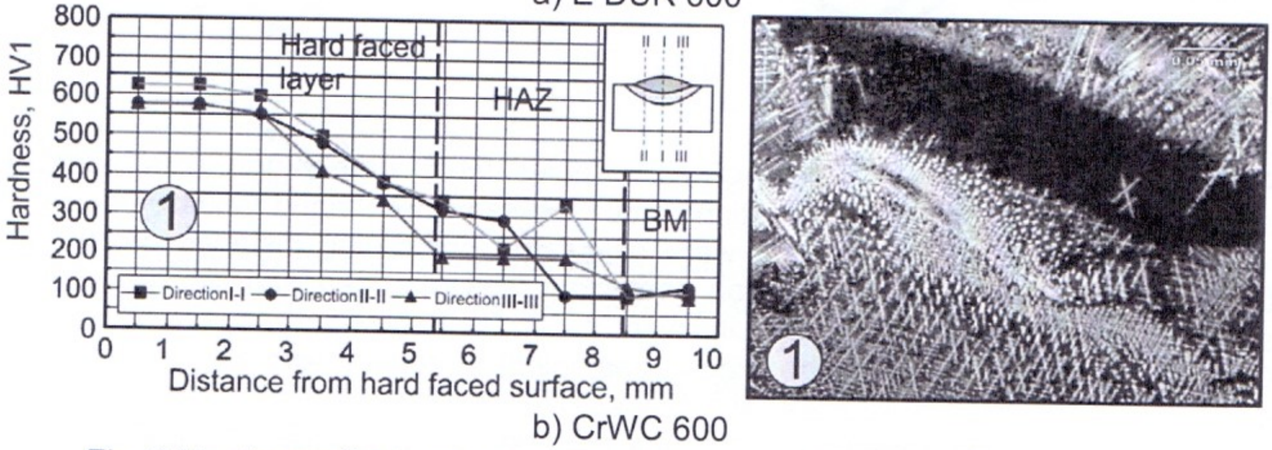


Fig. 2 Sample No. 1 - Directions of hardness measurement



a) E DUR 600



b) CrWC 600

Fig. 3 Hardness distribution and microstructure of two used filler materials

Microstructure of all the characteristic zones of the surfaced layer were analyzed on the same samples that were used for hardness measurement, however here are presented results for the surfaced layer's structure. Analysis was done on the optical microscope with magnifications 200× and 500×. Samples were etched by the 3 % nital solution and 4% vielle solution, when it was necessary.
Based on the optical metallographic analysis it could be assumed that in the part of the surfaced layer of sample # 1(E DUR 600), immediately next to the melting line (in the dissolution zone) predominant is the bainite micro constituent, with dendritically excreted carbides. Analysis of sample # 2 (CrWC 600) has shown the presence of the microstructure with prominent dendrite structure of casting and excreted carbides. Since this filler metal belongs into a group of highly alloyed (special) alloys with high content of chromium (26%) and tungsten (4%), the sample had to be etched with the 4% vielle solution to obtain the needed surface condition [16].
Due to limitations in micro structure estimates based on the light microscope analysis, to be absolutely certain about the present micro structures in samples, one must also perform the scanning electron microscope analysis (SEM) with the EDAX.

3.2 Tribological investigations

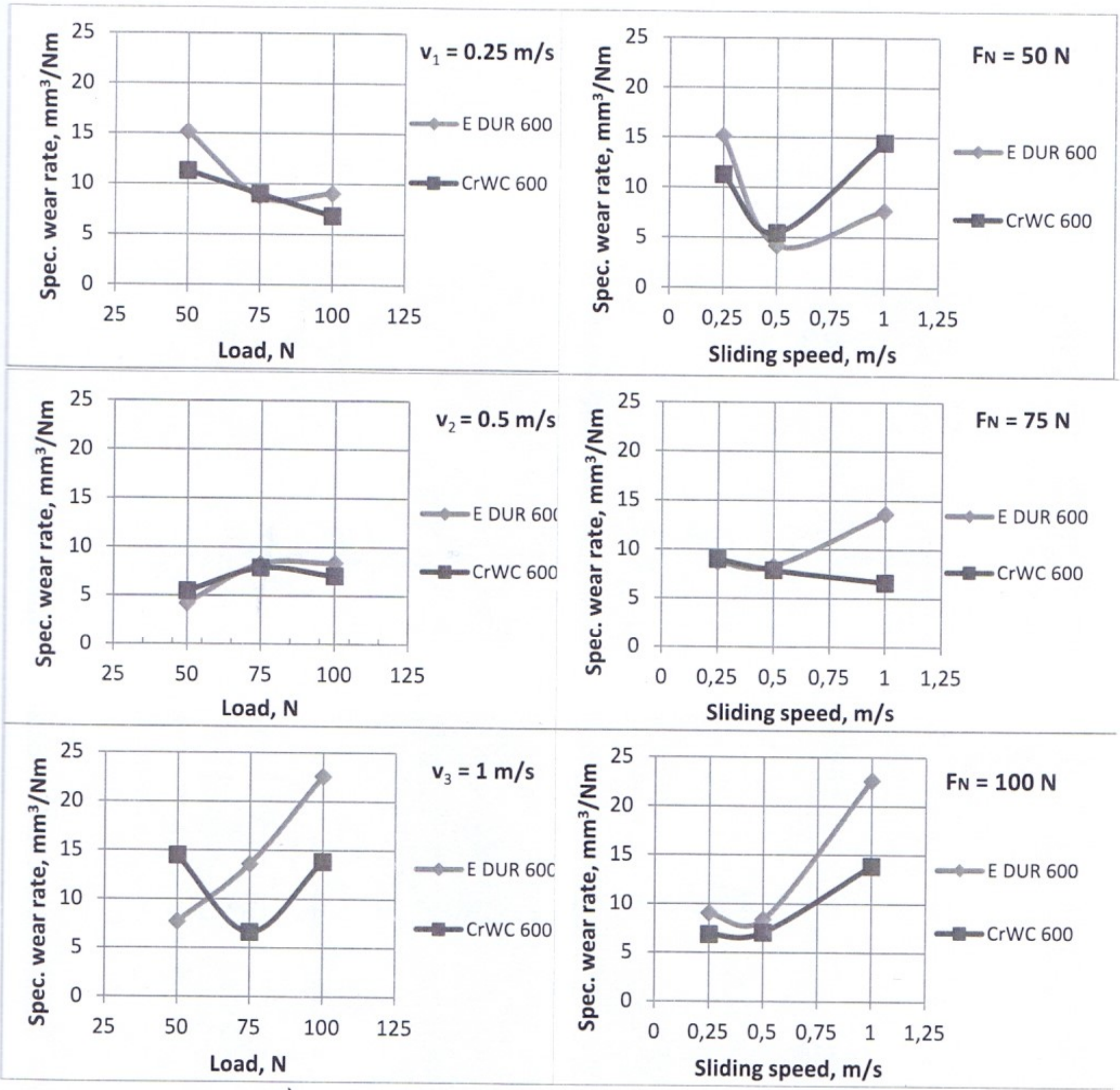
Tribological investigations were performed in Laboratory for Tribology at Faculty of Engineering in Kragujevac, by using tribometer TR-95. The objectives of those tests were to determine the wear resistance of joint base metal-hard faced metal for two different alloys. Samples for tribological testing, as prismatic blocks with dimensions 6.5×10×16 mm, were taken from pure hard faced layer. The testing was done as "block on disk" contact (Fig. 1d). External variables were the sliding speed and contact force. Because the working parts hard faced with these filler metals work without lubricating, tribological tests were executed in dry conditions. Prior to testing, the topography of discs and blocks has been measured on digital measurement system Taylor & Hobson Talysurf 6 in order to establish the quality of the machined/ground surfaces. It was confirmed that the samples were prepared with the same level of the machined surfaces quality.
Experiment assumed simulation of contact by using of three different sliding speeds (0.25 m/s, 0.5 m/s and 1 m/s) and three different loads (F_N = 50 N, F_N = 75 N and F_N = 100 N). Parameter for contact duration was sliding distance of 300 m. Parameters that were followed during the process were friction coefficient, wear volume and specific wear volume.

4. RESULTS

After testing, wear scare widths of all samples were determined using optical microscope UIM 21 with magnification of 50×. Based on obtained values, the wear volume and specific wear volume were calculated, for sliding distance of 300 m. During testing, the change of friction coefficient was recorded and the results are shown in Tab. 3. The results of specific wear volume are shown in Fig. 4.
Generally, one can say that the friction coefficient increases with load and sliding speed decrease in all the cases. The highest values of the friction coefficient were obtained for the sliding speed of 0.25 m/s and mainly for the lowest value of force (50 N), when the friction coefficient values exceeded 0.7.

Tab. 3. Mean values of the friction coefficient

		E DUR 600			CrWC 600		
		Sliding speed, m/s			Sliding speed, v, m/s		
	Load, N	0.25	0.5	1.0	0.25	0.5	1.0
Friction coefficient μ	50	0.675	0.546	0.534	0.604	0.618	0.562
	75	0.681	0.457	0.460	0.679	0.452	0.459
	100	0.599	0.395	0.397	0.598	0.395	0.396

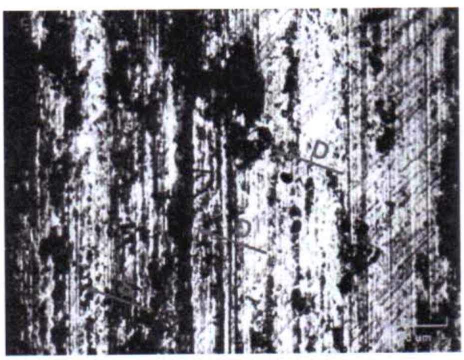


a) b)

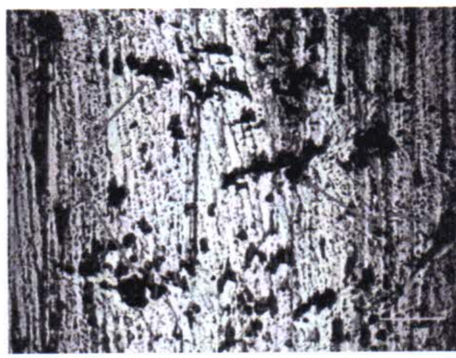
Fig. 4 Specific wear rate of the tested samples: a) at different sliding speeds and b) at different loads

By analyzing the real working conditions, one can say that parts surfaced by these materials operate in much rigorous conditions, i.e. higher sliding speeds (about 1 m/s) and larger forces (F > 100 N), what leads to the conclusion that the tested materials possess better frictional properties.

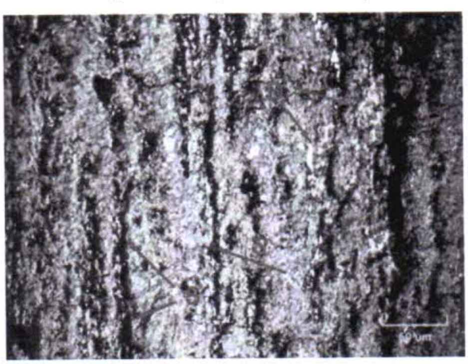
According to the Stribeck curve and behavior of the friction coefficient with sliding speed increase (slight decrease of the friction coefficient), it could be assumed that the test conditions were in boundary friction domain.
By analysis of obtained results, it can be said that in the contact zone appeared material particles detachment, which later can behave as abrasive particles and can cause further increase of damages. This surface is also characteristic for materials with high hardness.
Obtained results, presented in Fig. 4 show that the CrCW 600 alloy has somewhat better wear resistance since the worn material volume of those samples is smaller. As expected, results show that the wear increase occurs with increase of the sliding speed and the normal load. However, it is interesting to notice the behavior of the considered alloys at the speed of 0.25 m/s and force of 50 N, when the wear is the biggest at the lowest values of force and speed and later it decreases. In order to formulate the more precise conclusion about this phenomenon it is necessary to conduct some further investigations.



$F_N = 100$ N; $v_1 = 0.5$ m/s,

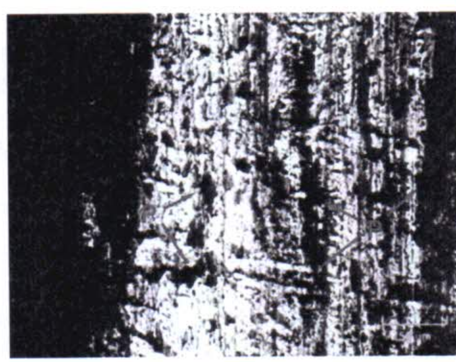


$F_N = 100$ N; $v_1 = 0.5$ m/s,



$F_N = 75$ N; $v_1 = 0.25$ m/s,

E DUR 600



$F_N = 75$ N; $v_1 = 0.25$ m/s,

CrWC 600

Fig. 5 Damages of samples: S – scratching, D – detachments, P – pits, (magnification 20×).

In the end, the surface of worn samples was recorded on optical microscope with magnification of 100×. In Fig. 5 are presented characteristic damages and wear scare of all tested specimens.

Damages presented in Fig. 5 show two different types of material wear. In the case of the E DUR 600 alloy, the characteristic is the phenomenon of scratching and crevices and material detachment, i.e. spots where material was "torn: from the surface. Material detachment is most probably caused by appearance of a crack, which propagates horizontally in the surface layer, what disturbs the metal continuity and causes conditions foe the stress increase and "wedging in" of abrasive particles. In the next phase, the detached material particles act as abrasive and considering that they have high hardness, they cause even larger and more prominent wear. In addition, in the vicinity of the spot from which the material was removed, the contact pressure increases, what further causes material degradation.

When the alloy CrWC 600 is concerned, it is characteristic that its wear is in the form of pits. They appear at points of the high pressure, due to which the initial micro cracks are propagating. The micro cracks are continuing to grow during the contact until the conditions are created for material particles to detach from the surface.

5. CONCLUSIONS

Through analysis of results, one can establish that both alloys have similar tribological properties, but by the detailed analysis of the monitored parameters, it was established that the alloy CrWC 600 has slight advantages:

- Hardness was about 600 HV1 at depth of 3 mm for the CrWC 600 alloy and at about 7 mm for the E DUR 600 alloy, while the higher hardness must not necessarily provide for the higher wear resistance.
- Microstructures were estimated as bainite with carbides and a small percentage of the residual austenite for the E DUR alloy and as dendrite casting structure with carbides for the CrWC alloy.
- Wear resistance testing was done in laboratory conditions, on a tribometer, where the specific volume of wear was monitored, depending on the force and sliding distance. The results thus obtained showed that somewhat higher wear resistance has the CrCW 600 alloy, especially at higher sliding speeds ($v = 1$ m/s) and forces ($F_N = 100$ N), what represents the sufficient criterion for selecting this materials as the optimal filler metal.

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