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WEAR RESISTANCE UNDER DRY CONDITIONS OF DIFFERENT FILLER METALS USED FOR HARD FACING

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Abstract: *The aim of this paper is to show wear properties of different types of filler metals aimed for hard facing and exploitation in dry condition. Testing of wear resistance is done in laboratory on prepared samples/models in order to simulate real exploitation conditions. Samples were made by hard facing of carbon steel using 4 different filler metals. Hard facing was done by using MMA welding method in three layers with enough height so samples could be made. After samples were made, the hardness and microstructure of all zones of hard facing were determined. Testing of wear resistance is done using block on disc contact on samples made from pure weld metal. As a parameter for estimates of the wear resistance of models it was used volume of worn material in mm^3. Metallographic investigations and hardness measurements were used as additional parameter for drawing the conclusions.*

Keywords: *Hard facing, filler metals, hardness, microstructure, wear volume.*

1. INTRODUCTION

Numerous working parts of different technical systems are during the exploitation exposed to various types of complex wear processes. Since never one type of wear is dominant, it is very hard to determine which of the wear mechanisms lead to biggest damages. Usually, damages are consequences of coupled action of several wear mechanisms. That is why it is necessary to apply higher quality materials, which are resistant to wear and which can produce more working hours for the concrete machine part. On the other side, manufacturing of large parts with using of high-quality materials offten is very expensive. Than the problem could be solved by application of hard facing. Hard facing enables reparation of damaged parts or manufacturing of the new parts by depositing the high quality material on the cheaper material. In that way, one saves not only material and money, but also the time needed for revitalizing damaged parts, shortening the downtimes, etc [1]. There is many examples where hard facing was succesifully applied in order to achieve above mentioned goals such as: claddings for deep-hole drilling [2], rotary tiller blades [3], gears [4], mixer blades [5], etc.

In this paper, four different types of filler materials were used. These materials are aimed for hard facing of the parts exposed to intensive impact and abrasive wear, such as bucket teeth of excavator, parts for terrain leveling, mixer blades used in asphalt bases, teeth of stone mils, industrial gears, forging dies, etc [6]. During exploitation they are mainly in contact with various types of stones [7] and they are exposed to intensive wear what leads to surface damages.

2. EXPERIMENTAL PROCEDURE

Experimental testing of hard faced plates included preparation of samples for hardness measurement perpendicular to hard faced surface, investigation of microstructure of characteristic zones and samples from pure weld metal for tribological testing in order to determine wear resistance of hard faced layers.

2.1 Sample preparation

Samples were prepared from hard faced plates in Laboratory for welding and materials at Faculty of Engineering. Hard facing was done by manual metal arc welding method in three passes and three layers (Fig. 1). Filler metals were selected based on working conditions of the parts and properties that this kind of parts have to possess. All that imply that steel alloys with high carbon and chromium content can be good solution. The chemical composition of selected metals is given in table 1. Before welding plates were preheated at 300°C and hard facing was done according to parameters given in table 2.

Hard faced models are used to cut the blocks for tribological test (Fig. 1b) and metallographic samples – blocks out of them, as shown in Figure 1c. Height of the weld clading was about 10-11 mm. Tribological test-wear resistance was determined on samples-prismatic blocks takken from pure hard facing, with dimensions shown in Fig. 1. Testing was done Laboratory for Tribology at Faculty of Engineering in Kragujevac by using tribometer TR-95 and realized "block on disc" contact.

Disc used in contact with tested samples was made of high speed tool steel, with diameter of 35 mm and thickness of 6.35 mm (the same as the width of 6.35 mm at test sample block as shown in Fig. 1). All samples were grounded and disc was grounded after each testing. Variables were the contact force and sliding speed. Since that the working parts hard faced with these filler metals work without lubricating, tribological tests were conducted under dry conditions.

Table 1. Chemical composition of base metal and filler metals [6]

Steel/Electrodes	Alloying elements [%]										Hardness, HRC/HV
	C	Si	Mn	P	S	Cr	Mo	W	Cu	CEV	
S355J0	0.2	0.5	1.4	0.035	0.035	-	-	-	0.55	0.47	≈ 24/240
E DUR 600 DIN 8555: E 6-UM-60	0.5	-	-	-	-	7.5	0.5	-	-	-	≈ 60/600
CrWC 600 DIN 8555: E 10-UM-60-C	4.0	-	-	-	-	26.0	-	4.0	-	-	≈ 60/600
INOX B 18/8/6*	0.12	0.8	7.0	-	-	19.0	9.0	-	-	-	-
E Mn17Cr13	0.6	-	16.5	-	-	13.5	-	-	-	-	≈ 48/500

Table 2. Hard facing parameters for the MMA welding 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	125	25.5	≈ 2.42	10539
	CrWC 600	3.25	130	26	≈ 1.95	13867
	INOX B 18/8/6	3.25	115	24.5	≈ 2.00	11270
	E Mn17 Cr13	3.25	135	26	≈ 2.50	11232

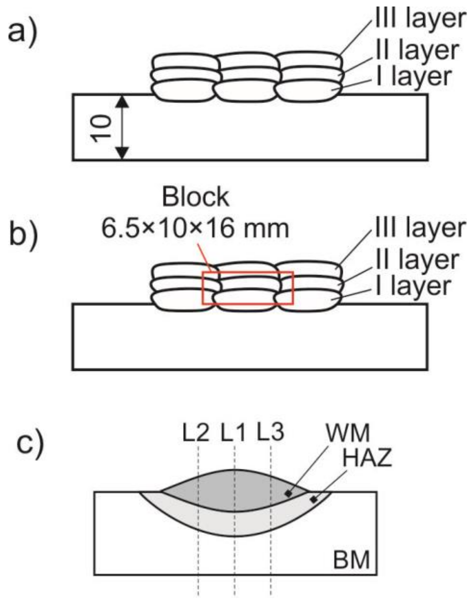


Figure 1. a) Order of layers deposition; b) blocks for tribological "block on disk" contact; c) metallographic ground slit

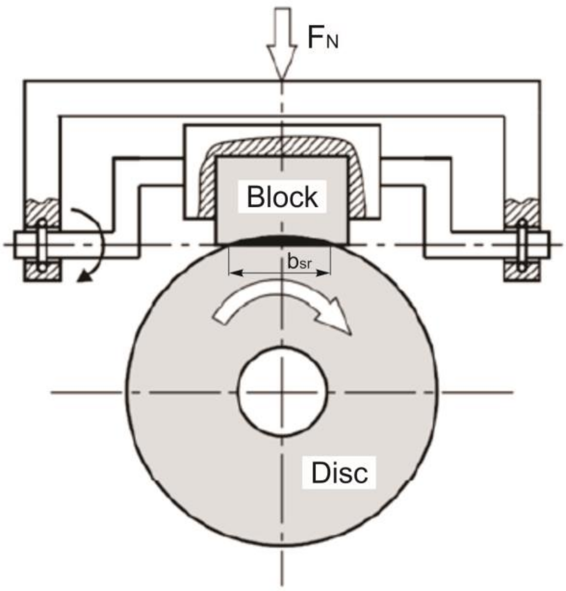


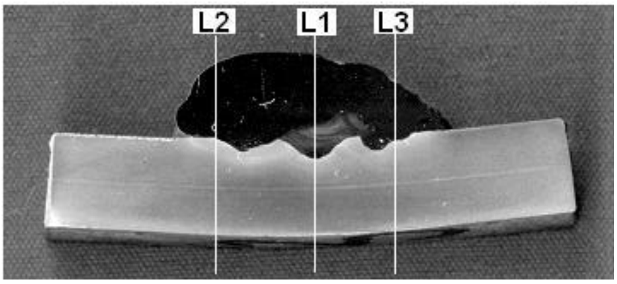
Figure 2. "block on disc" contact

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 i F_N = 100 N). Parameter for contact duration was sliding distance of 300 m. Parameters that were followed during process were wear volume and specific wear volume. The wear behavior of the block was monitored in terms of the wear track width, using the wear track width and the geometry of contact pair to determine the wear volume in mm^3 over the sliding distance.

Hardness has been measured on surfaces of metallographic samples in different directions. The same samples were used to estimate the microstructure of characteristic surfaced zones. Samples were chosen to be geometrically similar to hard faced part and they were made either of well weldable steel S355J0 (according to DIN: St St52-3U). Large number of parts in construction machinery is made of S355J0 steel, this is way this steel was used as base metal, but due to its poor wear resistance there is need for alloying or hard facing [8].

In Fig. 3 are shown 4 hard faced plates before cutting and one sample prepared for hardness measurement and microstructure estimation.

a)

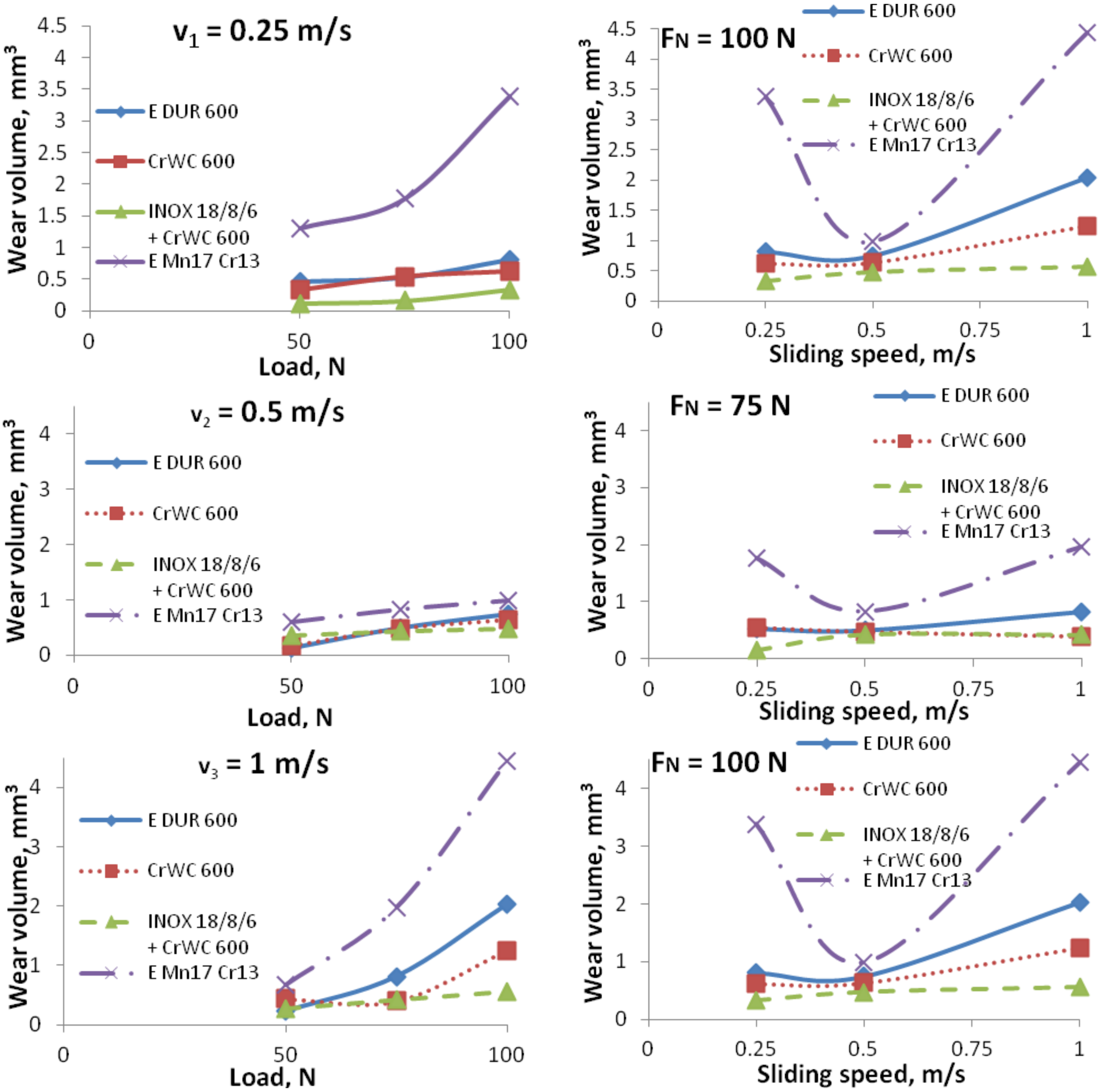


b)

Figure 3. Hard faced plates (a) and sample no. 3 prepared for hardness measurement

3. RESULTS

After testing, wear scar width of all samples were determined using microscope UIM 21 with magnification of 50×. Based on obtained values, the wear volume and specific wear volume was calculated, for sliding distance of 300 m. The results of wear volume obtained by experiment are shown in Figure 4 [6].

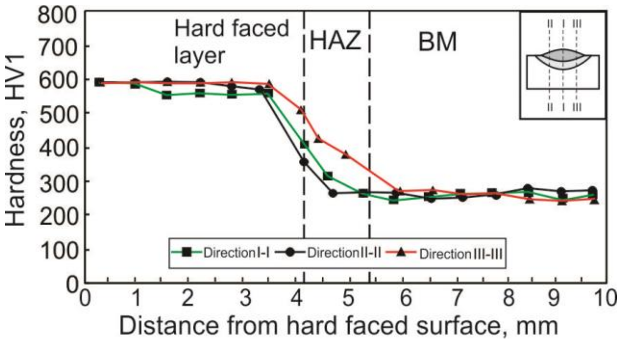


a) b)

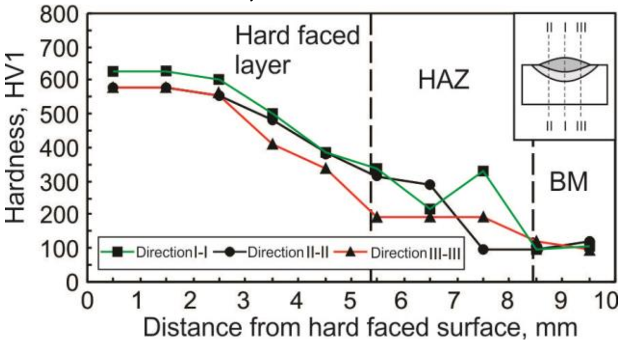
Figure 3. Wear volume of the tested samples: a) at different sliding speeds and b) at different loads

Based on presented results it can be concluded that the best wear resistance has the filler metal designated as CrWC 600 (sample #3). The best results were obtained using all three sliding speeds of 0.25, 0.5 and 1 m/s and almost all used loads. The function of the interlayer is to absorb impacts during exploitation, as well as to replace preheating when it is impossible to apply it (while it is predicted by the welding technology). Samples #1 and #2 has a little bit lower wear resistance than Sample # 4. The worse wear properties have a filler metal with high manganese content – Sample #4. It should be taken into account that this filler metal is aimed for cold hardening because of hammering or exploitation (deformation induced the transformation of austenite into martensite), leading to an increase in hardness.

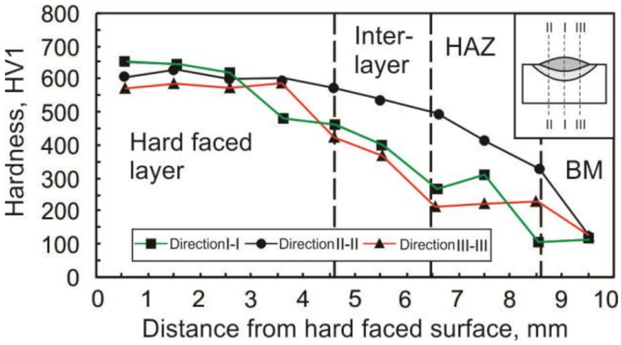
Hardness measurement was done by using Vickers method HV1 [9] along vertical line on hard faced sample. Obtained results are shown on diagrams at Fig. 4. Samples were prepared by water jet cutting in order to avoid overheating in cutting zone and potential change of structure. After cutting samples were grounded and polished. Hardness was measured along three vertical lines (as shown at Fig. 4).



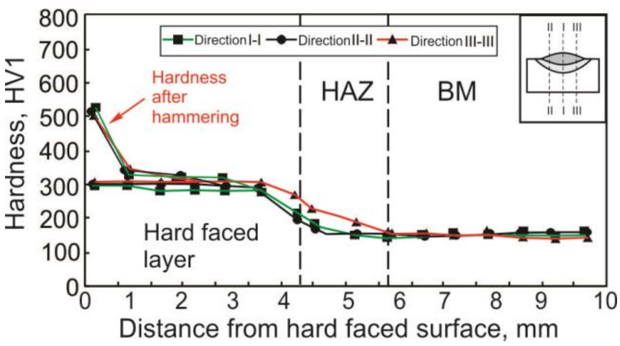
a) E DUR 600



b) CrWC 600



c) CrWC 600; Interlayer INOX B 18/8/6



d) E Mn17 Cr13

Figure 4. Hardness distribution of four samples

Presented hardness distribution is showing that hardness of all samples is approximately 600 HV in the zone of filler metal and dropping when going down to the base metal. High hardness can reduce wear, but also beside hardness, microstructure of the hard facing has to be suitable. Microstructure found at these samples was mostly prominent dendrite casting structure with excreted carbides. Dendrites are formed due to high carbon content while carbides are formed in presence of Cr, Mo and W. High carbide hardness has positive effect on wear resistance, especially when they are uniformly distributed in metal matrix [10, 11].

4. CONCLUSION

Analyzing the results, it can be concluded that the best tribological properties and wear resistance have the filler metal designated as CrWC 600 (sample #3), deposited with or without an austenitic interlayer. The best results were obtained using all three sliding speeds of 0.25, 0.5 and 1 m/s and almost all used loads. In the case of other samples – #1 and #2 – the main conclusion is that their wear resistance is a little bit lower than that for Sample # 4. The worse wear properties have a filler metal with high manganese content – Sample #4. It should be taken into account that this filler metal is aimed for cold hardening because of hammering or exploitation (deformation induced the transformation of austenite into martensite), leading to an increase in hardness. However, the conclusion is that it also cannot drastically affect the tribological properties of this filler metal and that this filler metal should not be recommended for reparatory hard facing of parts exposed to intensive abrasive wear and impact loads.

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REFERENCES

[1] V. Lazić, R. Čukić, S. Aleksandrović, D. Milosavljević, D. Arsić, B. Nedeljković, M. Đorđević, Techno-economic justification of reparatory hard facing of various working parts of mechanical systems, Tribology in Industry, Vol. 36, No. 3, pp. 287-292, 2014.

[2] J. Truhan, R. Menon, F. LeClaire, J. Wallin, J. Qu, P. Blau, The Friction and Wear of Various Hard-face Claddings for Deep-hole Drilling, Wear, Vol. 263, pp. 234-239, 2007.

[3] A. Singh Kang, G. Singh Cheema, S. Singla, Wear Behavior of Hardfacings on Rotary Tiller Blades, Procedia Engineering, Vol. 97, pp. 1442-1451, 2014.

[4] S. Marković, Lj. Milović, A. Marinković, T. Lazović, Tribological Aspect of Selecting Filler Metal for Repair Surfacing of Gears by Hard Facing, Structural Integrity and Life, Vol. 11, No. 2, pp. 127-130, 2011.

[5] V. Lazić, M. Jovanović, D. Milosavljević, M. Mutavdžić, R. Čukić, Choosing of the Most Suitable Technology of Hard Facing of Mixer Blades Used in Asphalt Bases, Tribology in Industry, Vol. 30, No. 1&2, pp. 3-10, 2008.

[6] D. Arsić, V. Lazić, S. Mitrović, D. Džunić, S. Aleksandrović, M. Đorđević, B. Nedeljković, Tribological behavior of four types of filler metals for hard facing under dry conditions, Industrial Lubrication and Tribology, Vol. 68, No. 6, pp. 729-736, 2016.

[7] V. Lazić, D. Arsić, R. Nikolić, B. Hadzima, M. Mutavdžić, Experimental determination of mechanical characteristics of four types of stones and their influence on the construction machinery parts wear, Advanced Materials Research, Vol. 1100, pp. 178-184, 2015.

[8] N. Thongchitrugsa, A. Chianpairot, F. Hartung, G. Lothongkum, Effect of molybdenum on wear resistance of Cr-Nb Hard-faced S355JR steel, Materials Testing, Vol. 56 No. 3, pp. 191-197, 2014.

[9] ISO 6507-1:2018 Metallic materials – Vickers hardness test – Part 1: Test method.

[10] V., Lazić, D., Milosavljević, S., Aleksandrović, G., Bogdanović, B., Nedeljković:, Carbide type influence on tribological properties of the hard faced steel layer – part I – theoretical considerations, Tribology in Industry, Vol. 32, No. 2, pp. 11-20, 2010.

[11] V., Lazić, D., Milosavljević, S., Aleksandrović, G., Bogdanović, B., Nedeljković, Carbide type influence on tribological properties of the hard faced steel layer – part II – experimental results, Tribology in Industry, Vol. 32, No. 3, pp. 3-12, 2010.