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Abrasion resistance of GMA metal cored wires surfaced deposits

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Abstract: A study was undertaken of four iron and two cobalt based hardfacing alloys as GMA cored wire surfaced to evaluate quantitatively their low-stress abrasion resistance as a function of chemical composition and hardness. ASTM G 65 Procedure A was used as the method of abrasion resistance evaluation. The most important variable in determining low-stress abrasion resistance was found to be chemical composition (microstructure) of the deposit. One and three layer deposits of high chromium cast iron and cobalt alloy based alloys have shown highest abrasion resistance, over 2,5 times higher than HARDOX 400 steel. Hardness has secondary effect on abrasion resistance and can not be use as the abrasion resistance indicator. Dilution has an important effect on abrasion resistance of iron based alloys.

Keywords: cobalt based alloy; Hardox 400; abrasion resistance

1. INTRODUCTION

Semi- and automatic GMA flux and metal cored wire surfacing is one of most popular method of surfacing of new or worn machine parts. It is possible to deposit layers in all positions with efficiency from a few up a dozen or so kilograms of weld metal deposit per hour [1-5].

Modern metal cored wires allow to deposit layers providing a broad spectrum of almost optional chemical compositions e.g. iron based alloys including ferritic/bainitic alloys, martensitic alloys, mixed martensitic/austenitic alloys, austenitic alloys, austenitic manganese alloys, primary austenite with austenite-carbide eutectic, primary carbides with austenite-carbide eutectic, nickel and cobalt based alloys and metal-ceramic materials, e.g. nickel or cobalt alloys with primary WC or W_2C carbides [1-5]. All these materials are GMA surfaced on new or worn working surfaces of machine parts or elements to provide specific properties as abrasive and adhesive wear resistance, erosion resistance, corrosion resistance, heat resistance and many of theirs combinations [1-5]. It is reported that 50-60% of machine elements are worn due to abrasive wear which has many forms including low stress, high stress, dry or wet abrasion [1]. Abrasion resistance of GMA surfaced layers is a function of many factors but basic are chemical composition and microstructure which on other hand depend on GMA surfacing parameters.

One of the primary criterions of determination optimal surfacing parameters, especially in case of surfacing of deposits that chemical composition strongly differs from base metal chemical composition, is to provide minimal dilution of the first layer of deposit:

$$U = \frac{F_{BM}}{F_{BM} + F_R} \cdot 100\% \quad \text{(dilution of the deposit by melted base metal)}$$

where: F_{BM} – area of base metal melted, F_R – area of reinforcement of the deposit (i.e. surfacing metal added).

Dilution of the GMA metal cored wire surfaced deposit can be controlled from 10% to over 40%, depending on surfacing parameters (heat input of surfacing) and technique of surfacing [1,4]. Technique of GMA cored wire stringer bead multi-layers surfacing makes possible to achieve dilution of second layer of deposit in the range of 5-15% but efficiency of GMA surfacing is lowest. Another solutions providing significant reduction of dilution is low heat input surfacing of stringer bead deposits and/or employing push technique of GMA surfacing.

Thus, abrasion resistance and hardness tests of GMA cored wire surfaced single layer (high dilution) and three-layer (low dilution) stringer bead deposits four iron and two cobalt based hardfacing alloys were done and compared to HARDOX 400 steel abrasion resistance.

2. **ABRASION RESISTANCE TESTS**

To determine quantitatively the wear resistance of GMA surfaced single and three layer stringer bead deposits of four metal cored wires EnDOTec DO*13, EnDOTec DO*16, EnDOTec DO*31 and EnDOTec DO*329 iron based hardfacing alloys and EnDOTec DO*60 and EnDOTec DO*70 cobalt based hardfacing alloys, Table 1, in comparison to HARDOX 400 wear plate wear resistance, Table 2, the tests of abrasive wear type metal-ceramic were conducted in accordance to standard ASTM G 65 - Standard Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus. Procedure A of the ASTM G65 standard was chosen.

For all of abrasion resistance tests of GMA surfaced deposits of six metal cored wires, Table 1, the base plate was TStE 355 steel - DIN 17102 (S355NL - EN 10 113), 12 mm thick, by 120 [mm] wide and 150 [mm] in length. All GMA surfacing was done using stringer beads, with no preheat and maximum interpass temperature of 250°C for three layers deposits. GMA robotized surfacing parameters of single layer and three layer stringer bead deposits were selected in the range of the field of optimal GMA surfacing parameters, Table 1, providing almost the same value of heat input of surfacing. Robotized GMA metal cored wire surfacing was conducted on the welding stand equipped with TotalArc² 5000 CASTOLIN programmable power source and SRV6 REIS welding robot.

The 25 [mm] wide and 75 [mm] in length abrasion test coupons were cut from single and three layers deposits and all test coupons were surface ground smooth and weighed to the nearest 0,0001 [g] as required by ASTM G65. Next abrasion resistance test was conducted. The force applied pressing the test coupon against the wheel was TL = 130[N] (test load - TL) and 6000 revolutions of the rubber wheel at 200 [rpm]. After the abrasion resistance test, the test coupon was weighed at weight sensitivity 0,0001 [g]. Mass loss was reported directly and relatively in comparison to the mass loss of the reference HARDOX 400 wear plate which is chosen as the reference material for all tested coupons of metal cored wires deposits, Table 2. Next the density of tested weld metal deposits and reference HARDOX 400 wear plate was measured and abrasion tests results were reported as volume loss in cubic millimeters by converting mass loss to volume loss as follows:

Volume loss, (mm^3) = [mass loss (g) **:** density (g/cm^3)] x 1000………(1)

Table 1.
Classification, chemical composition, typical hardness and GMA surfacing parameters of the deposits of six metal cored wires of test coupons for the abrasion resistance tests as per ASTM G65 - Procedure A

Coupons designation	Chemical composition and typical hardness of the deposit	Surfacing parameters		
		Current [A]	Voltage [V]	Heat input [kJ/mm]
EnDOTec DO*13	**Fe** + 0,45%C, 3,0%Si, 0,5%Mn, 9,5%Cr, 0,02%P, 0,01%S; 56-**58 HRC**	160-170	18,5-19,0	0,62
EnDOTec DO*16	**Fe** + 0,3%C, 0,5%Si, 0,5%Mn, 0,02%P, 0,02%S, 2,5%Cr, 0,6%V, 4,0%W; **48-50 HRC**	160-170	19,0-19,5	0,63
EnDOTec DO*31	**Fe** + 3,5%C, 1,2%Si, 0,8%Mn, 0,2%Ni, 30,0%Cr, 0,02%P, 0,01%S **55-60 HRC**	160-170	22,0-22,5	0,68
EnDOTec DO*329	**Fe** + 0,4%C, 0,5%Si, 0,7%Mn, 2,4%Cr, 0,5%Mo, 2,2%Co, 0,5%V, 7,5%W; **50-55 HRC**	140-150	19,5-20,0	0,58
EnDOTec DO*60	**Co** + 1,0%C, 0,5%Si, 0,8%Mn, 0,01%S, 29,0%Cr,4,5%W, 3,0%Fe; **40-42 HRC**	145-150	20,5-21,0	0,58
EnDOTec DO*70	**Co** + 1,7%C, 0,5%Si, 0,8%Mn, 0,01%S, 29,0%Cr,4,5%W, 3,0%Fe; **48-50 HRC**	140-145	19,5-20,0	0,60

Remarks: Welding speed of surfacing 5,0 [mm/s], all tested metal cored wires diameter = 1,6 [mm]. Shielding gas 97%Ar+2,5%CO_2, flow rate 18,0 [l/min]. Wire stick out 22,0 [mm].

Table 2.
Chemical composition wg %, of the materials used as the base plates for GMA surfacing of metal cored wire deposits for abrasion resistance tests and the reference HARDOX 400 wear plate

Base and reference wear plate	C	Mn	Si	P	S	Cr	Ni	B	Mo	HBW
S355NL	0,18	1,36	0,45	0,02	0,02	0,09	0,10	-	-	-
HARDOX 400	0,14	1,6	0,7	0,025	0,010	0,50	0,25	0,004	0,25	370-430

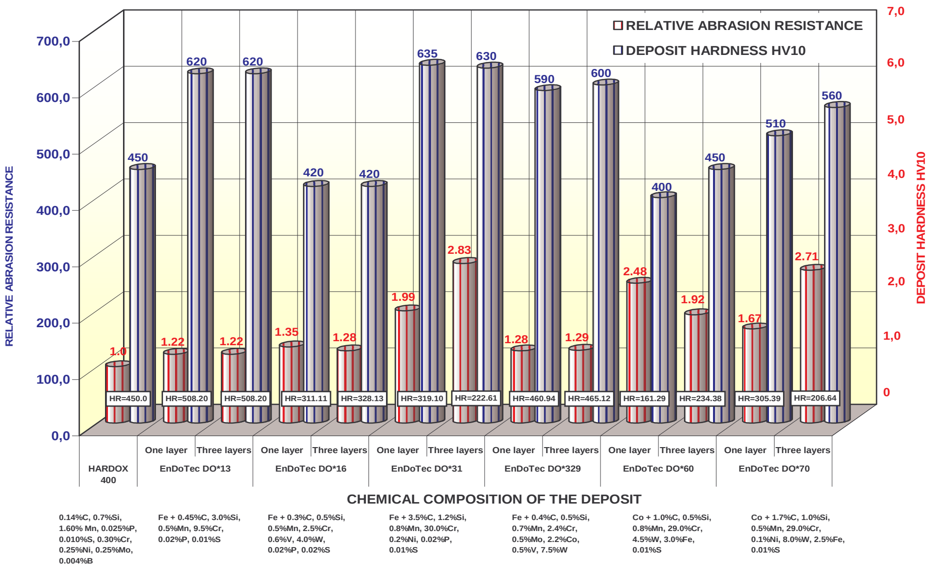

Figure 1. The influence of the chemical composition of the GMA surfaced one and three layers deposits of metal cored wires EnDOTec DO*13, EnDOTec DO*16, EnDOTec DO*031, EnDOTec DO*329, EnDOTec DO*60, EnDOTec DO*70, on the deposits abrasion resistance and surface hardness HV10 in relation to the relative abrasion resistance of HARDOX 400 wear plate

3. CONCLUSIONS

1. Low-stress abrasion resistance to metal-ceramic scratching by means of dry Ottawa quartz sand in accordance to standard ASTM G65 Procedure A of GMA surfaced single and three layers stringer bead deposits of all tested metal cored wires, Table 1, is exceeding over 1,22 to 2,83 times abrasion resistance of HARDOX 400 wear plate, Fig.. 1.
2. For all wires tested, but EnDOTec DO*31, three layers stringer bead deposits (low dilution) present almost the same abrasion resistance as one layer deposits (higher dilution), what is very positive indication of technological features of wires, allowing to achieve expected rheological and mechanical properties just in the single layer deposit. On the other hand single layer deposit of EnDOTecDO*60 wire has over 20% higher abrasion resistance than three layers deposit, probably due to lower dilution of the third layer deposit and as the result lower alloying of cobalt based deposit by iron of base metal.
3. The highest abrasion resistance is shown by metal cored wire EnDOTec DO*31 of high chromium cast iron structure and EnDOTec DO*70 cobalt based alloy deposits. Single layer of EnDOTec DO*31 deposit has 1,99 times higher and three layers deposit has 2,83 times higher abrasion resistance in comparison to abrasion resistance of HARDOX 400 wear plate as this wire is designated to increase metal-ceramic abrasion resistance [1].
4. It has been proved that there is very reliable correlation between abrasion resistance and chemical composition (microstructure) of the GMA surfaced single and three layers deposits of all tested metal cored wires, Tables 1 and 2, Fig. 1, but on the other hand, hardness is very poor indicator of abrasion resistance, as the ratio of hardness to abrasion resistance (HR) which should be expected to be on the same level is much higher for deposits showing lower abrasion resistance, for example HARDOX 400 wear plate shows HR = **450,** EnDOTec DO*13 deposit shows HR = 620:1,22 = **508,2** but EnDOTec DO*70 deposit HR = 510:2,67= **191**, Fig 1.

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