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The study of properties of Ni-W_2C and Co-W_2C powders thermal sprayed deposits

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Abstract: Samples of a carbon steel base metal were thermal sprayed by self fluxing cobalt and nickel base alloys (PE 8961 and PE 1229 powders blended with 50 or 60% of tungsten carbides W_2C). Six samples of every one PE 8961 and PE 1229 powders thermal sprayed deposits (further called PE 8961 deposit and PE 1229 deposit) with dimensions were provided for following tests: ASTM G65 procedure abrasive wear resistance test, hardness tests and metallographic examinations. It was shown that the abrasive wear resistance of PE 1229 deposit is 2,5 times higher than PE 8961 deposit and 27,9 times higher than reference 400HB steel and 33,8 times higher than reference AISI 316L steel.

Keywords: Thermal sparying; Wear plates

1. INTRODUCTION

Samples provided to the study are self fluxing cobalt and nickel base alloys (PE 8961 and PE 1229 powders blended with 50 or 60% of tungsten carbides W_2C), thermal sprayed on a carbon steel base metal, Table 1. Six samples of every one PE 8961 and PE 1229 powders thermal sprayed deposits (further called PE 8961 deposit and PE 1229 deposit) with dimensions 71x22x13,5 [mm], were provided for following tests:

- ASTM G65 Procedure A abrasive wear resistance test,
- Hardness tests,
- Metallographic examinations.

Results of abrasive wear resistance of PE 8961 and PE 1229 deposits shall to be compared to abrasive wear resistance of 400HB low alloy steel and AISI 316L Cr–Ni-Mo corrosion resistant austenitic steel.

2. ABRASIVE WEAR RESISTANCE TESTS OF ONE LAYER DEPOSITS OF TEROMATEC 4666 WIRE IN ACCORDANCE TO ASTM G 65-00

To determine quantitatively the abrasive wear resistance of PE8961 deposits and PE 1229 deposits, Table 1, in comparison to abrasive wear resistance of 400HB and AISI 316L steel plates, the tests of abrasive wear type metal-ceramic were conducted in accordance to standard ASTM G65 - Standard Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus. Procedure A of the ASTM G65 standard was chosen. Quartz

Ottawa sand was used for the tests. Sand had tightly limited particle size in U.S. sieve size -50 to +70 (-300 to + 212 microns) and moisture content under 0,5% weight. The rate of sand flow through the special nozzle, in the shape of thin layer between the test piece and a hard rubber wheel 229 [mm] in diameter, was adjusted at the rate 300-400 [g/min].

Table 1.
Chemical composition %wg. of tested materials

Deposits and reference steel plates	C	Si	Fe	Cr	Ni	B	Mo	W	Co	Others
Co-WC deposit	1,55	1,38	0,7	22,6	27,6	1,96	-	3,9	Bal.	blended 50% W_2C
Ni-WC deposit	0,1 max	1,36	6,2	7,4	Bal.	3,2	-	-	-	blended 60% W_2C
400HB	0,14	1,6	Bal.	0,50	0,25	0,004	0,25	-	-	1,6%Mn
AISI 316L	0.023	0,43	Bal.	17,13	11,13	-	2,05	-	-	1,25%Mn

Table 2.
Results of low-stress abrasive wear resistance to metal-ceramic scratching by Ottawa quartz sand of PE 8961 and PE 1229 deposits and 400HB steel and AISI 316L steel

Specimen designation	Number of deposit	Weight before test [g]	Weight after test [g]	Mass loss [g]	Average mass loss [g]	Average volume loss [mm^3]	Relative* abrasive wear resistance
PE 8961	P1.1	155,9115	155,7350	0,1765	0,1677	16,522	11,2/13,6
	P1.2	153,1631	153,0041	0,1590			
PE 1229	P2.1	152,4276	152,3598	0,0678	0,0690	6,666	27,9/33,8
	P2.2	150,8331	150,7629	0,0702			
400HB	H1	62,2260	60,7526	1,4734	1,4617	185,7306	1,00
	H2	63,1222	61,6721	1,4501			
AISI 316	A1	42,9163	41,0881	1,8282	1,7974	225,5207	0,82
	A2	44,2162	42,4495	1,7667			

Remarks: Density of PE 8961 deposit – 10,15 [g/cm^3] PE 1229 deposit – 10,35 [g/cm^3], 400HB steel - 7,87 [g/cm^3], AISI 316L - 7,97 g/cm^3]. * - relative to the abrasive wear resistance of reference 400HB steel/316L steel.

The 22 [mm] wide, 72 [mm] in length and 11,6-11,9 [mm] thick abrasive wear test specimens were machined form samples of tested deposits and all test specimens were surface ground smooth and weighed to the nearest 0,0001 [g] as required by ASTM G65 Procedure A. Next abrasive wear resistance test was conducted. The force applied pressing the test specimen against the wheel was 130 [N] and 6000 revolutions of the rubber wheel at 200 [rpm]. After the abrasive wear resistance tests, every test specimen was weighed, at weight sensitivity 0,0001 [g]. Mass loss was reported directly and relatively in comparison to the mass loss of the 400HB and AISI 316L steel plates, which were chosen as the reference materials for all tested specimens of deposits, Table 2. Next the density of tested PE 8961 and PE 1229 weld metal deposits and reference 400HB and AISI 316LL steel plates was measured using pycnometer (specific gravity bottle) and abrasive wear tests results were reported as volume loss in cubic millimeters, Table 2, by converting mass loss to volume loss as follows:

$$\text{Volume loss, } [mm^3] = \text{mass loss } [g] : \text{density } g/cm^3] \times 1000 \qquad (1)$$

PE 8961 DEPOSIT PE 1229 DEPOSIT

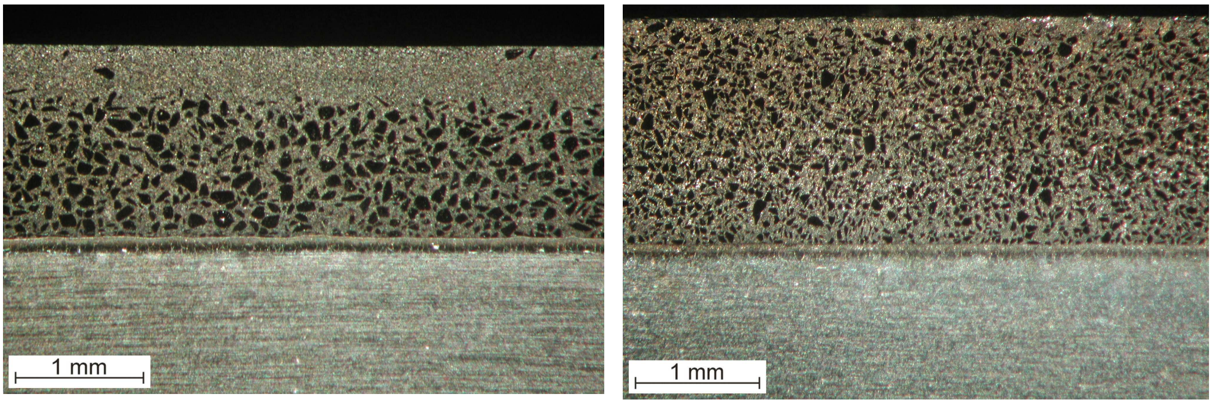

Figure 1. Macrographs of PE 8961 and PE 1229 thermal sprayed deposits

PE 8961 DEPOSIT PE 1229 DEPOSIT

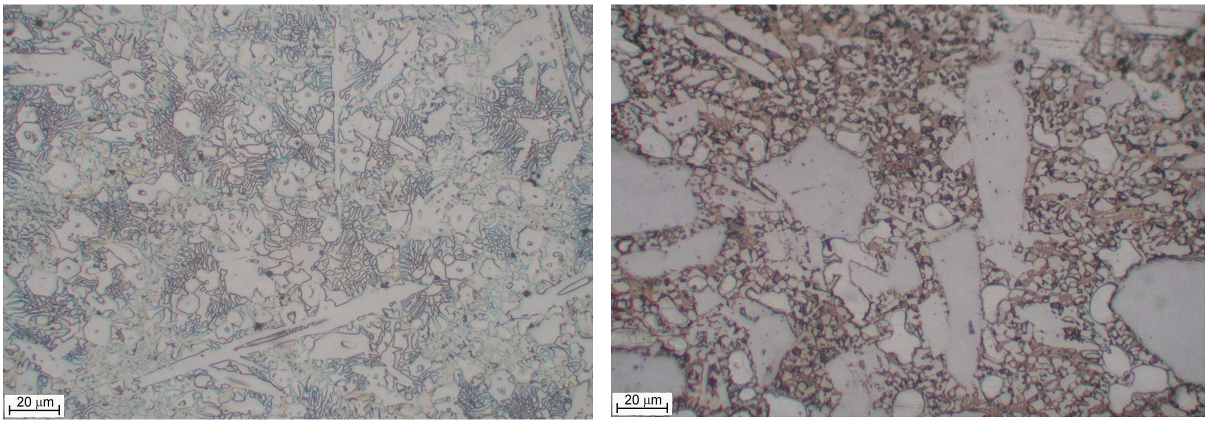

Figure 2. Microstructures of PE 8961 and PE 1229 powders thermal sprayed deposits in undersurface area

3. HARDNESS TESTS

To test hardness of PE 8961 and PE 1229 deposits and reference materials HV10 hardness test was chosen to provide very high accuracy of hardness measurements of low thickness deposits. Two hardness measurements were taken on the 0,5 [mm] deep ground surface of PE 8961 and PE 1229 deposits and reference 400HB and AISI 316L steel plates to provide information of deposit surface hardness in real abrasive wear conditions, on the cross-section of PE 8961 and PE 1229 deposits and reference 400HB and AISI 316L steel plates.

4. METALLOGRAPHIC EXAMINATIONS

Samples of PE 8961 and PE 1229 deposits were cut in half and prepared by grinding, next STRUERS machine polishing and etching by $FeCl_3$ aqueous solution to metallographic examinations of macrostructures and microstructures of deposits. Results of macrostructure and microstructure examinations proved high quality of both tested deposits, Figs. 1 and 2.

5. CONCLUSIONS

Abrasive wear resistance of PE 1229 deposit is 2,5 times higher than PE 8961 deposit and 27,9 times higher than reference 400HB steel and 33,8 times higher than reference AISI 316L steel, Table 2, what is confirmed by results of metallographic examinations and hardness tests.

Hardness of PE 1229 deposit when measured on the deposit ground surface is very high, over 900 HV10 and on the cross section is 778-853 HV10. Hardness of PE 1229 deposit is much higher than PE 8961 deposit i.e. 656 HV10 measured on the deposit ground surface and 525-789 HV10 on the cross section is, Tables 2.

Metallographic examinations of PE 8961 and PE 1229 deposits show very high quality of deposited weld metal and uniform shape of deposit/base metal interface of deposits of thickness approx. 30-40 [μm], Fig. 1.

Population density of tungsten carbides in PE 1229 deposit is much higher than in PE 8961 deposit, Fig. 2, and size of tungsten carbides in the middle area and fusion zone area is 30-40% smaller than tungsten carbides of PE 8961 deposit.

PE 8961 deposit shows free of tungsten carbides undersurface layer of thickness approx. 450 [μm], Fig. 2, confirming results of surface and cross section hardness measurements. PE 1229 deposit free of tungsten carbides undersurface layer is very narrow, just 75 [μm] thick and hardness of this region is very high. Free of tungsten carbides very thick undersurface layer of PE 8961 deposit probably forms due to bigger size of high density tungsten carbides (density of W_2C - 15,72g/cm^3) sinking to the bottom of lower density cobalt alloy matrix of PE 8961 weld pool (density of Co – 8,85 [g/cm^3]). Higher quantity (60% of W2C blended with nickel alloy powder - density of Ni – 8,9 [g/cm^3]) of much smaller size tungsten carbides of PE 1229 deposit provides much higher hardness and much narrower undersurface layer of deposit free of tungsten carbides.

Some influence on the thickness of free of tungsten carbides undersurface layer of PE 8961 deposit could have technique of thermal spraying.

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