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Abrasive Wear Behavior of Different Thermal Spray Coatings and Hard Chromium Electroplating on A286 Super Alloy*

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ABSTRACT

In cases of decorative and functional applications, chromium results in protection against wear and corrosion combined with chemical resistance and good lubricity. However, pressure to identify alternatives or to improve conventional chromium electroplating mechanical characteristics has increased in recent years, related to the reduction in the fatigue strength of the base material and to environmental requirements (1). In the present study plasma sprayed coatings (aluminum oxide, Co-28Mo-8Cr-2Si, tungsten carbide, chrome carbide) and electrolytic hard chrome coatings abrasive wear properties have been compared. The wear tests were conducted with a Taber abraser, at room temperature.

Keywords: Thermal Spray; Abrasive Wear; Electrodeposited Hard Chrome; Hardness; SEM

1. Introduction

Chromium has been widely used in surface finishing of metals because of the favorable properties it imparts to substrates and because the processes used are relatively mature, well understood, widely specified, and cost effective (2). This coating is produced from a wet chemical bath containing hexavalent chromium ions (Cr^{+6}). In all environmental regulations, Cr^{+6} is classified as a confirmed human carcinogen. Hard chromium plating produces large volumes of chromium containing toxic waste, air pollution and water contamination (3). Potential process substitutions for hard chromium plating are electroless nickel in certain applications, several nickel-tungsten composite plating, and spray applications such as plasma spray coatings (2). Plasma spraying is a process widely used in industry for depositing protective and functional coatings for a large variety of applications. Industrial sectors such as aerospace, automotive, energy, mining, biomedical, etc. take advantage of the unique properties of the sprayed coatings (4). The applications of thermal spray coatings are extremely varied, but the largest categories of use are to enhance the wear and/or corrosion resistance of a surface (2). The deposition methods for the wear protective coatings are atmospheric plasma spraying (APS) and high velocity oxygen fuel (HVOF) flame spray processes. Both of these methods have their own characteristics, e.g. different spray particle velocities and flame temperatures. As a result, the coatings have different microstructures and properties (5).

2. Experimental Coatings

As aforementioned, electroplated chrome and four kinds of plasma spray were involved in the study. Their characteristics are listed in **Table 1**. The A286 super alloy was used as substrate materials for all five coatings. The thicknesses of coating layers were controlled in the range of 100-150 µm. The substrates were sand blasted prior to spraying using 36 grit alumina sand. Sulzer Metco 9MB plasma gun and GH / 732 nozzles were used. The spraying parameters were given in **Table 2**.

Table 1. The characteristics of the present coating materials.

Designation	*Composition (wt.%)*	*Powder size (µm)*
Aluminum oxide	Al_2O_3 %3 TiO_2	-45 +11
T400	Co-28Mo-8Cr-2Si	-45 +15
Tungsten carbide	WC %12Co	-45 +15
Chrome carbide	%75 Cr_3C_2 %20 Ni %5 chromium	-45 +5

Table 2. Spray parameters.

Coating Materials	Aluminum oxide	T400	Tungsten carbide	Chrome carbide
Plasma gases	Ar + H_2	Ar + H_2	Ar + H_2	Ar + H_2
Plasma gases flow rates (scfh)	100 - 15	120 – 12,5	110 – 12,5	90 - 10
Plasma gases pressure (psig)	100 - 50	90 - 50	100 - 50	100 - 50
Current (amper)	500	500	400	500
Spray distance (inch)	4,5	4,5	4,5	4,5
Traverse speed	%90 - 2	%80	%95	%100
Powder feeder carrier gas pressure (psig)	50	50	50	50
Powder feeder carrier gas flow (scfh)	13,5	13	13,5	15
Feed rate (g/min)	50	45	30	50
Air jet	-	Paralle, 50 psi	Parallel, 60 psi	Parallel, 50 psi

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Electroplated chrome coatings were produced in an industrial plant, using the industrial deposition parameters listed in **Table 3**. The de-hydrogenation thermal treatment (200^0C for 3 h) has also been performed on the coating.

2.1. Characterization

Roughness was measured with Diavite DH-5, also hardness off each coating were measured by the Vickers microhardness tester (Wilson/Tucon) and given in **Table 4**.

The thicknesses of the coatings were determined by micro hardness tester (Wilson/Tucon). Scanning electron microscopy technique (SEM) was used to observe two different parts of the test coupons which performed abrasive wear test (right) and which didn't (left).

2.2. Abrasive Wear Tests

For abrasive wear tests, samples were prepared from A286 with 4 mm thickness and 100 mm square, according to FED-STD-141C. AMS 5525 (A286 plate form), electrolytic hard chrome and aluminum oxide, Co-28Mo-8Cr-2Si, tungsten carbide, chrome carbide plasma spray coated test panels were subjected to abrasive wear test. The wear tests were conducted with a Taber abraser, at room temperature, using a 1000 g load and CS-17 abrading wheel. The results were analyzed by wear index (mg/1000 cycles) and total wear (mg/10000 cycles) data. Cycles to mg/1000 weight loss is shown in **Table 5** and **Figure 1**, cycles to total mg weight loss is given in **Table 6** and **Figure 2**.

3. Results and Comments

In this study, heat treated electrolytic hard chrome and aluminum oxide, Co-28Mo-8Cr-2Si, tungsten carbide and chrome carbide plasma spray coated test coupons were characterized and abrasive wear behaviors were evaluated.

Table 3. Hard chrome deposition parameters.

Bath composition	CrO_3 250 g/l; H_2SO_4 2.5 g/l; no additives
Bath temperature (^{0}C)	52-57
Voltage (V)	2.5-3
Approximate current density (A/dm^2)	≈ 40
Bath stirring method	Pneumatic stirring

Table 4. Coating roughness and Vickers microhardness of coatings.

Coating	Roughness; R_a (μm) (lt = 4.8; lc = 0.8)*	Standard deviation	Vickers microhardness (HV 0.1)	Standard deviation
Electrolytic hard chrome	144,2	16,87	662,27	4,56
Aluminum oxide	237,09	22,36	695,34	167,2
Co-28Mo-8Cr-2Si	248	29,05	484,93	45,23
Tungsten carbide	284,05	23,1	932,98	314,6
Chrome carbide	205,05	14,63	772,92	79,45

Table 5. Abrasive wears weight loss (Cycles – weight loss, mg/1000).

Cycles	mg/1000					
	A286	K[1]	19[1]	36[1]	37[1]	38[1]
0	0	0	0	0	0	0
1000	0,02665	0,00958	0,0946	0,1405	0,22907	0,1655
2000	0,0091	0,00647	0,05117	0,072	0,07357	0,0677
3000	0,0054	0,00598	0,03313	0,0513	0,06627	0,0594
4000	0,01705	0,0057	0,0317	0,0332	0,05997	0,0236
5000	0,00995	0,0041	0,0281	0,0308	0,05827	0,0185
6000	0,00475	0,00325	0,05883	0,05155	0,06223	0,0485
7000	0,0167	0,0056	0,05597	0,0469	0,0543	0,02395
8000	0,00685	0,00355	0,0508	0,0455	0,0442	0,0124
9000	0,00715	0,00435	0,04853	0,0351	0,03363	0,0255
10000	0,01385	0,00445	0,04703	0,04295	0,02333	0,0217

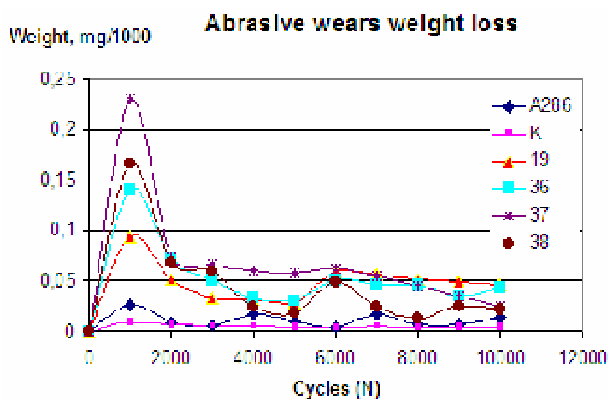

Figure 1. Abrasive wear weight loss vs. number of cycles.

Table 6. Abrasive wears weight loss (Cycles – Total weight loss, mg).

Cycles	Total mg					
	A286	K[1]	19[1]	36[1]	37[1]	38[1]
0	0	0	0	0	0	0
1000	0,02665	0,00958	0,0946	0,1405	0,22907	0,1655
2000	0,03575	0,01605	0,14577	0,2125	0,30263	0,2332
3000	0,04115	0,02203	0,1789	0,2638	0,3689	0,2926
4000	0,0582	0,02773	0,2106	0,297	0,42887	0,3162
5000	0,06815	0,03183	0,2387	0,3278	0,48713	0,3347
6000	0,0729	0,03508	0,29753	0,37935	0,54937	0,3832
7000	0,0896	0,04068	0,3535	0,42625	0,60367	0,40715
8000	0,09645	0,04422	0,4043	0,47175	0,64787	0,41955
9000	0,1036	0,04858	0,45283	0,50685	0,6815	0,44505
10000	0,11745	0,05302	0,49987	0,5498	0,70483	0,46675

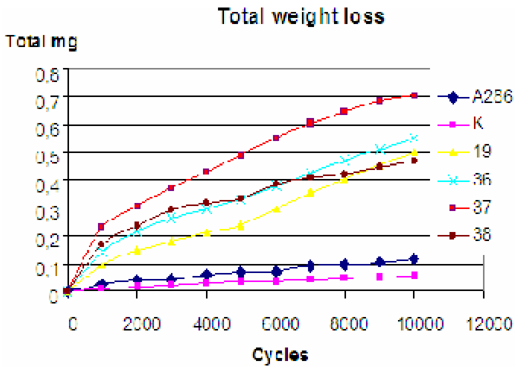

Figure 2. Total weight loss vs. number of cycles: K : Electrolytic hard chrome, 19 : Aluminum oxide, 36 : Co-28Mo-8Cr-2Si, 37 : Tungsten carbide, 38 : Chrome carbide.

Experimental data from abrasive wear tests were conclusive, indicating better results from the hard chrome coating. The abrasive wear resistance of plasma spray coatings and hard chromium plating was evaluated and the results in terms of wear weight loss are represented in **Table 5**, **Table 6** and **Figure 1**, **Figure 2**. The hard chromium plating on A286 substrate material shows better wear resistance properties. Hard chromium coating reduces the abrasion rate of the substrate material.An initially higher wear weight loss for the plasma spray coatings occurred, decreasing continuously and then nearly stabilized. However, the stabilized abrasive wear rates were still higher than the hard chrome coatings.

The initial peak which is typical for plasma spray coatings (**Figure 1**) was due to the higher surface roughness. **Table 4** figures out that the surface roughness values of all other coating materials are higher than those of electrolytic hard chrome. Plasma sprayed materials show rough surface properties, involving many pores, oxides and inclusions.

It is possible to compare the tested coating materials with electrolytic hard chrome coatings on the SEM micrographs which were given in **Figure 3**. It can clearly be observed that the electrolytic hard chrome coatings show dense and smooth surface properties. On the other hand, the plasma spray coatings have porous coating structure.

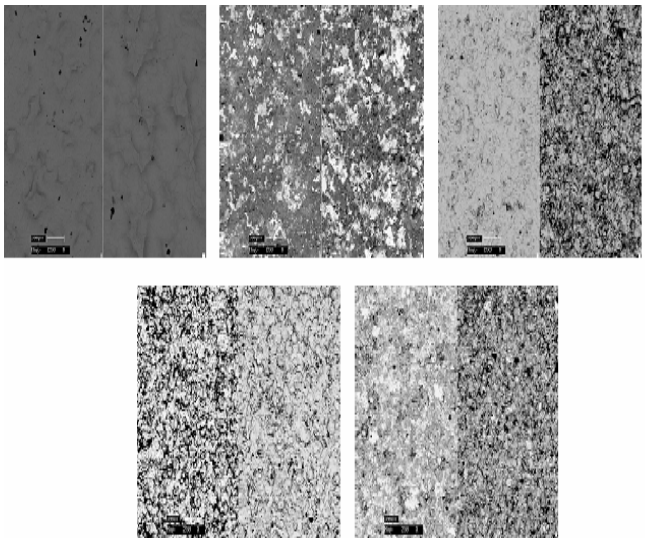

Figure 3. SEM micrographs of electrolytic hard chrome and plasma spray coatings (for each coating, left side picture non-weared, right side picture weared (From left to right electrolytic hard chrome, aluminum oxide, Co-28Mo-8Cr-2Si, tungsten carbide, chrome carbide) (250 X)).

In terms of hardness values, as it can be seen on **Table 4**, in comparison with the electrolytic hard chrome coated test coupons, similar or higher hardness values were reached by plasma spray coated test coupons.

As it can be seen in **Table 5**, **Table 6** and **Figure 1**, **Figure 2**, aluminum oxide coatings show better abrasive wear resistance among all plasma spray coupons. This is due to high oxide content of the coating material. Coating of high oxide content is usually harder and is more wear resistant [6].

REFERENCES

[1] M.P. Nascimento, R.C. Souza, I.M. Miguel, W.L. Pigatin, H.J.C. Voorwald, Effects of tungsten carbide thermal spray coating by HP/HVOF and hard chromium electroplating on AISI 4340 high strength steel, Surface Coatings & Technology, vol. 138, pp. 113-124, 2001.

[2] ASM handbook Volume 5: Surface Engineering, 1994.

[3] B.Navinsek, P.Panjan, I.Milosev, PVD coatings as an environmentally clean alternative to electroplating and electroless processes, Surface Coatings&Technology, vol. 116-119 pp. 476-487, 1999

[4] L.Pawlowski, The Science and Engineering of Thermal Spray Coatings, John Wiley, New York, 1995.

[5] D.Toma, W. Brandl, G. Marginean, Wear and corrosion behaviour of thermally sprayed coatings, Surface Coatings & Technology, vol. 138 pp. 149-158, 2001.

[6] H.J.C. Voorwald, R.C. Souza, W.L. Pigatin, M.O.H. Cioffi, Evaluation of WC-10Co-4Cr thermal spray coatings by HVOF on the fatigue and corrosion strength of AISI 4340 steel, Surface Coatings & Technology, vol. 190, pp. 155-164, 2005.

