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Wear and corrosion of metal-matrix (stainless steel or NiTi)-TiC coatings

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Abstract

Different spraying technologies (plasma and High Velocity Oxi-Fuel) have been use to obtain TiC - stainless steel or NiTi matrix coatings. The starting feedstock powders have been obtained by SHS technology. After crushing and sieving, the fraction of particles between 20 and 63 µm, have been selected for thermal spray. The obtained coatings have been characterized by XRD and SEM-EDS to observe the surface and cross section. The coatings adhesion, wear (ball-on-disk and rubber wheel tests) and electrochemical corrosion test have been carried out.
Results show that the plasma sprayed coatings with NiTi have better adhesion than the stainless steel matrix coatings. However, the opposite happens for HVOF coatings. NiTi matrix coatings exhibit higher wear resistance both for plasma and HVOF spraying processes.

Keywords: NiTi; wear; thermal spray coatings; metal-matrix composites

1. Introduction

Hard carbide composites are recognised as good candidates for applications under extreme wear conditions due to their mechanical properties. The TiC-metallic matrix is a good candidate to replace WC-Co because of the higher temperature and oxidation resistance [1, 2]. TiC particles were chosen because they do not damage seriously the counterpart by friction during sliding [3]. The binder phase is the most vulnerable component of a sintered composite. Consequently, much effort has been devoted to study the interactions that occur between carbides and the matrix [4] and their influence on the final properties of the composite.

The toughness of the composite is obtained by means of the metallic matrix. This might be achieved using, for instance, an intermetallic as NiTi, or stainless steel. NiTi offers high oxidation resistance by means of the parabolic nature of its oxides which prevents from high rate oxidation at high temperatures [5]. Also, the thermomechanical properties of NiTi as pseudoelasticity might play a role in increasing the wear resistance. NiTi coatings obtained by thermal spray have been reported elsewhere [6].

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The self-propagating high temperature synthesis (SHS) provides a good technology to produce hard carbide composites with appropriate carbide size and distribution [9, 10]. In this work, we study TiC in NiTi matrix, and compare it to TiC in stainless steel matrix.

2. Experimental

The TiC-NiTi and TiC-stainless steel powders used were prepared using the SHS method. The composition of the powders (60-40% wt of carbide and binder respectively) was chosen to assure the quantity of metallic matrix phase to achieve enough cohesion of the TiC particles. The final products contained TiC particles between 3-8 µm approximately in the metallic matrix. The product was grinded and sieved to the final nominal size distribution (20-63µm).

An air plasma spraying gun F4 from Sulzer Metco was used to deposit coatings. A Diamond Jet Hybrid-DJH2700 was used to obtain the HVOF coatings. The spraying parameters of the processes are listed in Table 1. The substrate was a 34CrMo4 carbon steel (50 mm X 20 mm X 0.5 mm) and prior to coating the substrates were grit blasted with alumina to clean and roughen the surfaces. Final roughness was between 4-6 µm.

Table 1: Plasma and HVOF spraying parameters

Plasma parameters		HVOF parameters	
Current (A)	550-630	Carrier gas (air) flow (l/min)	370-380
Ar flow (l/min)	38-42	Propilene flow (l/min)	70-80
H_2 flow (l/min)	10-15	O_2 flow (l/min)	250-260
Spray distance (mm)	120	Spray distance (mm)	225
Feed rate (g/min)	15	Feed rate (g/min)	30

Identification of the present phases was carried out by XRD. Cross-sections of the coatings were investigated using a Jeol JSM 5310 scanning electron microscope coupled with an EDS (Röntec) analyser.

Tension tests were also carried out following the ASTM C-633 standard. The coatings were tested by dry sand rubber wheel abrasion test following ASTM G65-00. The normal force used was 50 N. Friction tests were done using ball-on-disk equipment according to ASTM G99-03. Specimens were pressed against a WC-Co, 16 mm ball under 10 N of load.

3. Results and discussion

Cross-section of plasma coatings is shown in Figure 1. Figure 2 shows cross sections of HVOF coatings. Uniform and relatively homogeneous coatings were obtained.

Some transverse microcracks are also found due to the different expansion coefficient of the TiC and the NiTi respectively. The cracks are mainly found in the outer part of the coating and are a result of the stress relaxation of the coating during cooling after thermal spraying. The NiTi matrix is affected by the deposition process whereas carbides are less affected. Several nickel rich phases (lighter colours, Figure 1) are present at the plasma coating, with the non-affected matrix (grey colours). A compromise between larger melting, cracking and good adhesion, or lower melting, less cracking and bad adhesion has to be achieved.

As it can be clearly seen, the carbide proportion is higher in the HVOF coating than that one obtained by plasma. No richer nickel phases were found in the NiTi matrix in the HVOF coating. The lower working temperatures required may be responsible of a less dilution of the carbides and to avoid titanium depletion in the matrix. Porosity is in this case estimated as 8%, as compared to 4% for the NiTi plasma coating. No cracks were found for this coating because of the low temperatures involved during the deposition process which gives lower thermal stresses.

(a) (b)

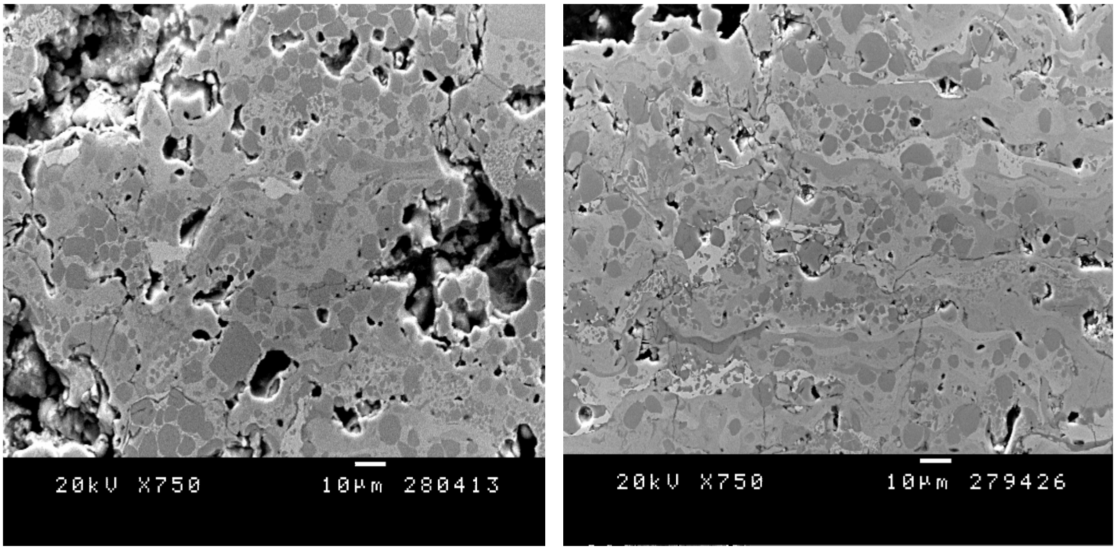

Figure 1a) Cross-section of TiC-stainless steel and b) Cross-section of TiC-NiTi obtained by plasma deposition

(a) (b)

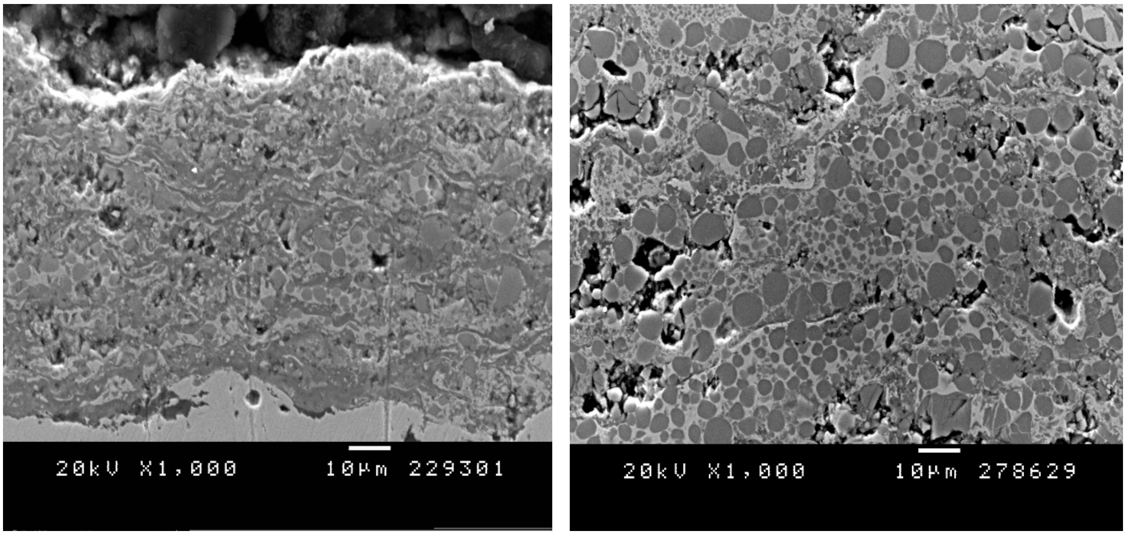

Figure 2 a) Cross-section of TiC-stainless steel and b) Cross-section of TiC-NiTi obtained by HVOF deposition

Table 2 shows the properties of the coatings. In all cases the failure takes place through the layer coatings. The lower value of the adherence of the NiTi HVOF coating, compared with the plasma one, is in agreement with the lower degree of melting during the deposition process.

Some further improvement of the HVOF NiTi coatings may be achieved by increasing the energy of the deposition process.

The friction coefficients for Plasma and HVOF NiTi coatings are quite similar; however the wear mechanisms are quite different. The properties of the NiTi matrix play an important role on the wear mechanism taking place. Ding et al. found that the stress relaxation of pseudoelastic matrix surrounding ceramics particles improves the wear resistance [7].

The corrosion potential of NiTi containing coatings is very near to the plasma deposited stainless steel coating and the value is also similar to the corrosion potential of the substrate. This suggests that the electrolyte can penetrate through the existing cracks to the substrate.

Table 2. Properties of the obtained coatings

	TiC-stainless steel		TiC-NiTi	
	Plasma	HVOF	Plasma	HVOF
Adherence (MPa)	33.2	53.4	58.1	43.4
Friction coefficient	0.68	0.30	0.51	0.48
Wear loss (mg/min)	4.0	2.8	0.4	0.9
Corrosion potential (mV)	-596	-693	-593	-584
Porosity (%)			4	8

4. Conclusions

The friction coefficient of NiTi coatings is higher than the stainless steel one. The properties of the HVOF TiC-stainless steel are better than that obtained by Plasma. This could be attributed to the large amount of carbide decomposition at higher temperatures of plasma. On the other hand, the opposite is found for the TiC-NiTi coatings. This may be due to a non complete optimization of the HVOF process suggested by the higher porosity found in these coatings. In spite of this fact, the NiTi coatings experience lower wear than the stainless steel. The high friction coefficient is attributable to the hard TiC while the low wear of the NiTi coatings should be attributed to the increased toughness, i.e. NiTi may show a linear stress/strain curve up to 1% in strain and this is not the case for stainless steel. In a limited temperature domain NiTi may recover more than 6% of strain through pseudoelastic behavior [6]. The combination of both effects help the system to have low wear.

Acknowledgements

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References

[1] S.N. Basu, V.K. Sarin. Mater. Science and Eng., A209, (1996), 206.
[2] S. K. Bhaumik, R. Balasubramaniam, G. S. Upadhyaya, M. L. Vaidya. Journal of Mater. Science Letters, 11, (1992), 1457.
[3] Jeong-Keun Lee. Wear, 265, (2008), 1584.
[4] A. Contreras, E. Bedolla, R. Pérez, Acta Materialia, 52, (2004), 985.
[5] L. Zhu, J. M. Fino, A. R. Pelton. Proceedings of SMST-2003 Monterey, CA (eds.) T.W. Duerig, A. Pelton
[6] N. Cinca, A. Isalgué, J. Fernández, J. M. Guilemany, ESOMAT 09, DOI:10.1051/esomat/200906006 published by EDP Sciences, 2009
[7] L.X. Ding, M. Kato, K. Nakasa, T. Inoue, Journal of the Japan Institute of Metals, 68, 8, (2004), 596.