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ScienceDirect
Corrosion Science 49 (2007) 2781–2799
CORROSION SCIENCE
www.elsevier.com/locate/corsci

Tribocorrosion behaviour of HVOF cermet coatings

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Received 7 March 2005; accepted 5 February 2007
Available online 4 March 2007

Abstract

The main purpose of this work is to analyze the degradation mechanisms induced on industrial HVOF cermet coatings by tribocorrosion. Tribocorrosion of cermet coatings is a subject that has not been widely analyzed in research studies: in fact, while many works dealing with wear or corrosion of HVOF cermet coatings are published, studies relevant to the combined processes (wear and corrosion) are relatively few.

The tribocorrosion mechanisms of the cermet coatings were studied in a sodium chloride solution under sliding wear, trying to combine and integrate differently produced mechanical and electrochemical damage phenomena.

Electrochemical techniques such as potentiodynamic polarization curves as well as potentiostatic (I vs t) or galvanostatic (E vs t) methods were used in order to stimulate and to interprete tribocorrosion degradation mechanisms.

It was shown that coating post grinding, which is a mechanical operation usually performed after the deposition of conventional cermet coatings in order to obtain a desired roughness, could produce structural damages, which can greatly affect the mechano-chemical behaviour of the cermet coatings.

Mainly abrasive–adhesive wear mechanisms were observed on the coating surface and sometimes, depending on coatings mechanical properties (fracture toughness), cracks developed during wear causing the coating continuity breaking. In the latter case, the degradation mechanism is no longer governed only by surface tribocorrosion, but undermining corrosion can occur, greatly affecting sample performances and promoting coating detachment.

Cr_3C_2–NiCr coatings, under all the selected experimental conditions, showed good barrier properties and substrate corrosion was never observed. Moreover, when chromium was added to the

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doi:10.1016/j.corsci.2007.02.003

metal matrix of WC–Co based systems, tribocorrosion behaviour was enhanced and the lower tribocorrosion rates were measured.

Finally, it was shown that electrochemical techniques can be used to govern the coating corrosion processes and to interpret the main degradation mechanisms, even though they seem not to provide a precise quantitative analysis of tribocorrosion.

Keywords: A. Metal matrix composites; B. Erosion; B. Potentiostatic

1. Introduction

The interaction between a mechanical and an electrochemical process is described as tribocorrosion [1–4]. Tribocorrosion is also defined as the chemical–mechanical process leading to a degradation of materials in sliding or rolling contact in a corrosive environment [5].

Cermet coatings are widely used in industrial applications against tribological degradation even in the presence of corroding environments, due to their high hardness and to the good corrosion resistance of the employed metal matrices. Cermet coatings are, in fact, composite materials, consisting of a very hard ceramic phase, mixed in an appropriate metal binder which supports coating toughness. These coatings are considered to be an excellent replacement for hard chromium plating, because no Cr^{6+} or other toxic substances are used during the deposition processes [6].

Among the thermal spraying technologies industrially used to deposit cermet coatings, high velocity oxygen fuel (HVOF) has proved to be particularly effective, producing very dense coatings with adhesion to the substrate and high hardness. The process is a low temperature method compared with other technique, it requires minimal base metal preparation and it can be directly applied to the working tools. In high velocity oxygen fuel thermal spray technology, oxygen and liquid fuel are combusted under high pressure in a chamber and the combustion products are accelerated through a converging–diverging nozzle [7]. The powder, fed into the hot stream of gases, is heated and then is accelerated on the substrate at very high speed (650–850 m/s) [8]. Because of the high velocity associated with a relatively low flame temperature, HVOF is considered a valid process to deposit cermet coatings of low porosity content (about 1%): in particular, HVOF allows creating denser and less oxidized coatings than conventional thermal spray technologies [9], and no significant thermal and mechanical alterations of the substrate are usually observed.

The most common HVOF cermet coatings are WC–Co, WC–CoCr and Cr_3C_2–NiCr systems. WC-based cobalt coatings are most widely used because of their superior wear resistance-strength combination [10]; the chromium addition to the metallic binder is thought to improve its corrosion resistance in comparison with pure WC–Co systems [11]. Cr_3C_2–NiCr coatings show poorer tribological properties but they are much more resistant at high temperatures and in aggressive environments: for these reasons they are used, for example, in steam turbine blades or in boiler tubes for power generation [12].

Many papers, in the literature, deal with the microstructural characterization of these coatings as a function of the deposition parameters, or with analysis of some technological properties such as wear or corrosion resistances, but few papers studied the behaviour under combined mechano-chemical degradation phenomena [13–15].