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Corrosive wear behavior of chromium carbide coatings deposited by air plasma spraying

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Abstract

The corrosive wear behavior of chromium carbide coatings deposited by air plasma spraying was studied, through wet pin-on-disk wear experiments. During the wear tests, the samples were immersed in corrosive environments consisting of watery hydrochloric acid with the acid concentrations of 5, 10 and 15 vol%. The wear tests were performed at both room temperature and 80 °C. The results showed that the wet environment significantly increased the wear rate. In addition, the increase of the acid concentration and temperature considerably deteriorated the wear resistance of the coated samples. It was also realized that, compared to the dry condition, the wear mechanism changed from abrasive to adhesive in the wet environment where a tribochemical wear was observed.

Keywords: A. Films; C. Wear resistance; D. Carbides

1. Introduction

Some of the common engineering materials are not suitable for working at high temperatures. Tungsten alloys are highly oxidized, a growing oxide layer is produced on iron alloys, nickel and cobalt alloys do not show appropriate mechanical properties, and thallium and niobium are highly solutionized at high temperatures. Hence, coatings with active elements are used as a thermal barrier to overcome high-temperature oxidation. These coatings are metal and ceramic layers that react with oxygen and produce a dense layer against the oxidation of the base metal [1–4].

Alumina is one of the coatings used at elevated temperatures, due to its acceptable corrosion resistance. This is, however, highly brittle and is frequently damaged during installation and thermal cycles [2,5]. This coating has been substituted by MCrAlY coatings since 60 decade [6]. The next generation of these coatings is chromium carbide coatings. These coatings are good barriers against heat with high hardness and strength, appropriate adhesion to substrate and presenting a stable oxide at high temperatures. One of the most common chromium carbides is Cr_3C_2 [1,7]. These coatings were applied on surfaces through cladding in the early times and could be hence used in complex parts like turbine blades. Newly developed coating methods like electron beam physical vapor deposition (EB–PDV),

Table 1
APS coating conditions.

Current (A)	Voltage (V)	Ar (SPLM)	H_2 (SPLM)	Powder feed rate (g/min)	Spraying distance (mm)	Gun translation speed (m/min)
600	60	60	5	40	150	75

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air plasma spraying (APS) and high velocity oxy fuel (HVOF) are common methods for chromium carbide coatings [8–11]. The chromium carbide is often mixed with nickel and chromium and the coating phenomenon is performed at high temperatures. In this method, the particles of Cr_3C_2 are substituted in the Ni–Cr layer [9].

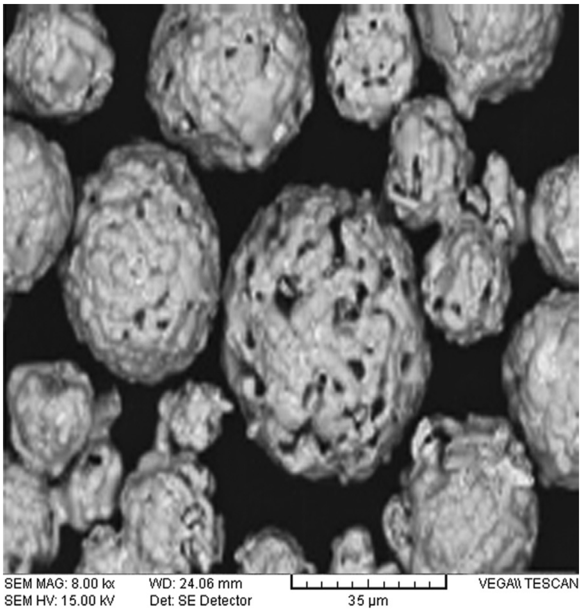
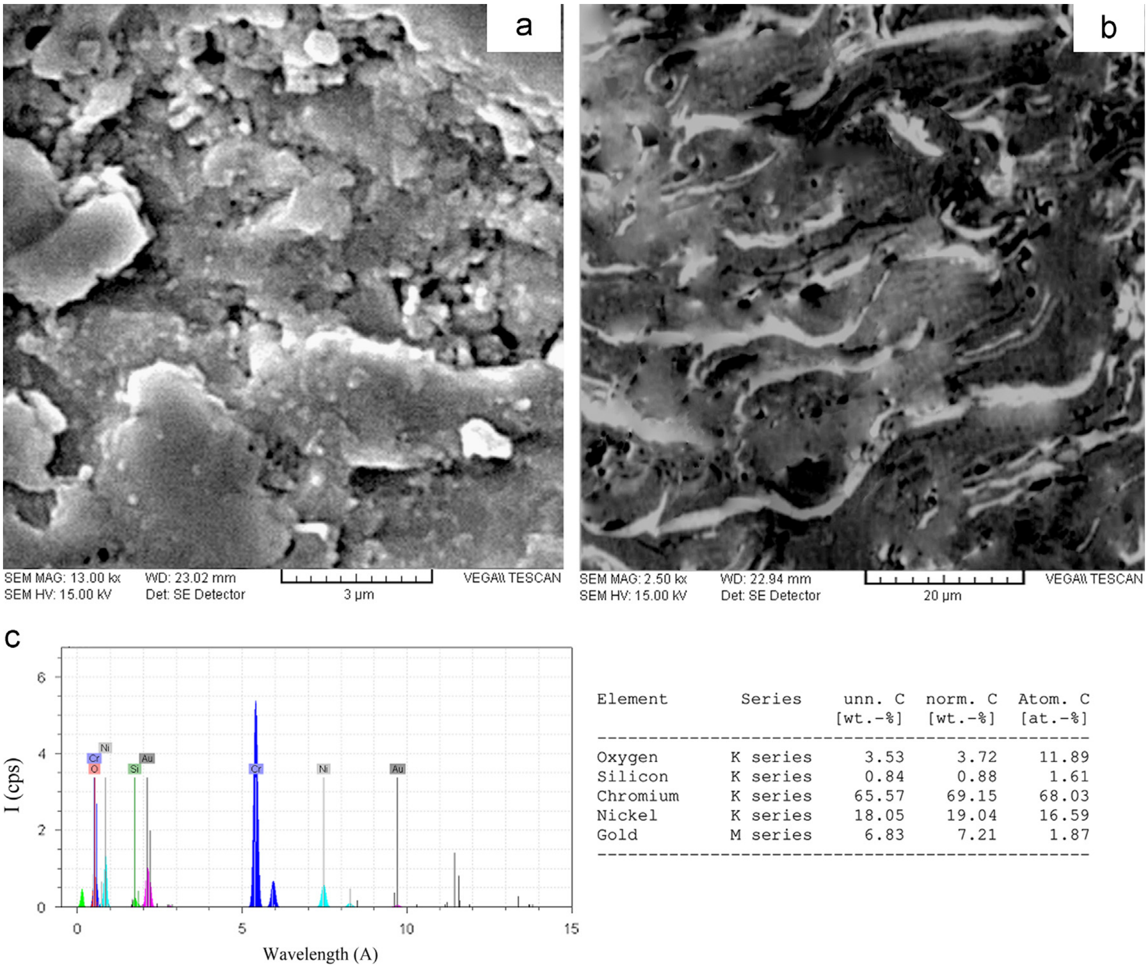


Fig. 1. SEM micrograph of the Cr_3C_2–NiCr particles before coating.

Thermal spraying methods have commonly been used for coating of thermal barrier coatings (TBC) since 1933. These methods are based on heating of the coating elements and spraying them on the substrate surface [12–14]. The heating of the powders can be performed by electricity or flame heating. In the APS method, the powders are heated through an electric arc and a plasma jet is used for heating and accelerating the semi-molten material to the substrate. In this method, the substrate is not regularly heated up to 150 °C; hence, the metallurgical properties of the substrate do not change after coating. The speed of the outlet material is a function of torch design, powder properties, plasma gas, torch working voltage and many other variables. The applied coatings are denser than those created by electric coating methods and can reach 85–90% of theoretical densities [12,15].

Many studies have focused on the effect of APS of chromium coatings on wear, high temperature wear and corrosion behaviors. Nevertheless, to the best of our knowledge, a few works have dealt with the effect of spontaneous wear and corrosion on the working life of these coatings. This study focused on the effect of corrosive wear at room



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Element        Series    unn. C  norm. C  Atom. C
                         [wt.-%]  [wt.-%]  [at.-%]
-------------------------------------------------
Oxygen        K series    3.53     3.72    11.89
Silicon       K series    0.84     0.88     1.61
Chromium      K series   65.57    69.15    68.03
Nickel        K series   18.05    19.04    16.59
Gold          M series    6.83     7.21     1.87
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Fig. 2. SEM micrograph of the chromium carbide coating: the top view (a), the cross section (b) and EDS analysis (c).