

Corrosion Behavior of WC Cermet Coating Sprayed by HVOF in Acid Solution

J. E. Cho, B. G. Seong, S. Y. Hwang, and K. Y. Kim

Materials and Processes Research Center, RIST,
P.O. Box 135 Pohang 790-330, Korea

The high-velocity oxygen-fuel (HVOF) sprayed coatings of tungsten carbide (WC) cermets were studied with respect to corrosion and corrosion-wear behaviors in acid solution. This report determined corrosion and corrosion-wear behavior of various WC coatings such as WC-Co, WC-Co-Cr, WC-Cr-Ni in acid solution. WC-Co coating suffered heavy corrosion of metal matrix and galvanic corrosion of WC particle/metal matrix in coating layer, WC-Cr-Ni coating identified being present of connected pores in coating layer which lead to rapid attack of steel substrate in acid solution. By using corrosion resistant substrate can prevent of localized corrosion. Overall it was concluded that the performance of some WC coating systems show good corrosion and corrosion-wear resistance using appropriate substrate.

Keywords : WC cermet coating, thermal spraying, corrosion, wear.

1. Introduction

WC cermet thermal spraying technique is well known to provide a wide variety coating materials having excellent performance characteristics under different aggressive condition such as wear, erosion. However these coatings are increasingly being required where corrosive attack is possible. In the aqueous solution thermal spraying of WC coatings often show poor performance and are spalling off the substrate during in service. There has been less attention paid to their corrosion properties.¹⁾ HVOF spray is a relatively new thermal spray technique, which propels powder material by supersonic flame jet to velocity well over 500 m/s. HVOF sprayed coatings are attractive for corrosion resistance, as they are dense with reduced oxidation of raw materials as compared to coatings formed by other atmospheric thermal spray processes such as plasma spray or wire arc spray.^{2),3)} Tungsten carbide (WC) coatings using HVOF coatings have capable of possessing wear, corrosion-wear and mechanical properties equal to or better than those of hard chrome plating. Hard WC particles form the wear-resistant constituent, while binder such as Co, CoCr, CrNi provides toughness and support of coating layer. Some recent studys stated corrosion resistant of coatings strongly depends on binder materials.^{4),5)}

Corrosion properties of binder are improved from a Co binder to a Ni, and further CoCr, CrNi in acid solution. In contact with chemically aggressive environmental, corrosion progresses by oxidation of the binder leaving only

WC particles which is easily broken down by mechanical action because metallic binder is located between WC particles, often in narrow area. Beside inherent general corrosion, galvanic corrosion may occur between different phases in the coating layer, between the coating and the substrate.^{6),7)} As part of a wider study concerning durability aspects of various thermal spray coating, this study relates to corrosion behavior and wear resistance of WC coatings in acidic solution.

2. Experimental

The HVOF spraying of WC cermet coatings was carried out with a Hobart Tafa Tech. Apparatus (Fig. 1) and JP-5000 HVOF system was used. Primary spraying conditions were used in manufacturing parameters.

Specifications of the coating powder and compositions are shown in Table 1.

Coating thickness approximately 100 μm and all specimens were polished to 1 μm diamond finish before test.

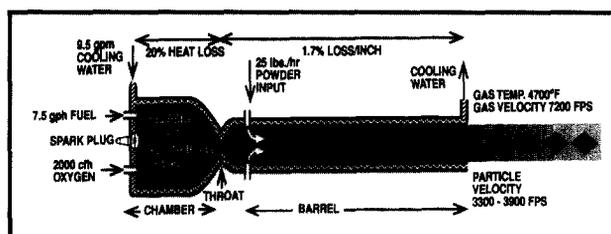


Fig. 1. Schematic view of JP-5000 HVOF gun.

Table 1. Specification of coatings

Specimen*	Composition (wt%)
WC-Co	WC-12Co
WC-Co-Cr	WC-10Co-4Cr
WC- CrNi	WC-20Cr ₃ C ₂ -7Ni

Substrate : STKM 13C(carbon steel), STS 316

Corrosion experiments were carried out by immersion in pH 0.3 sulfuric acid base solution. Electrochemical corrosion monitoring was performed on all coatings at a room temperature, aerated the same pH 0.3 acid solutions. EG & G 273A potentiostat/galvanostat and Flat cell were used. Corrosion-wear test was performed flat specimen and roll type counter specimen in acid solution and pure water. Scanning vibrating electrode technique (SVET) was used to identify galvanic effect between coating layer and substrate. The SVET has been developed to allow in-situ examination of localized corrosion activity through the detection of d.c. current variations associated with corrosion. 7 × 4 mm² area which is coating/substrate boundary was selected for scans.

3. Results and discussion

In Fig. 2 the coating integrity of WC-Co show a dense and WC particles being embedded in the Co matrix. In case of WC-CrNi the coating porosity is identical due to the less amount of Ni binder. Dark phase (B) was identified of Cr rich area by EDX analysis.

3.1 Electrochemical behaviors

Free potential of WC, W₂C are more noble than Co and Ni binder metal (Fig. 3 (A)). In acid solution there should be galvanic effect in coating layer. WC-Co specimen (Fig. 3 (B)) initially increase exponentially with increasing potential thereafter phenomenologically similar to passive behavior has been shown. The magnitude of current density remains so high around 200 (A/cm²) in comparison to general passive current density (below 10 (A/cm²)). At around 400 mV, all WC cermet coatings shows current increase with increasing potential. This is similar to typical trans-passive behavior. It's a the same result A. M. Human study⁸⁾ stated it's due to WC oxidation not surface film break down.

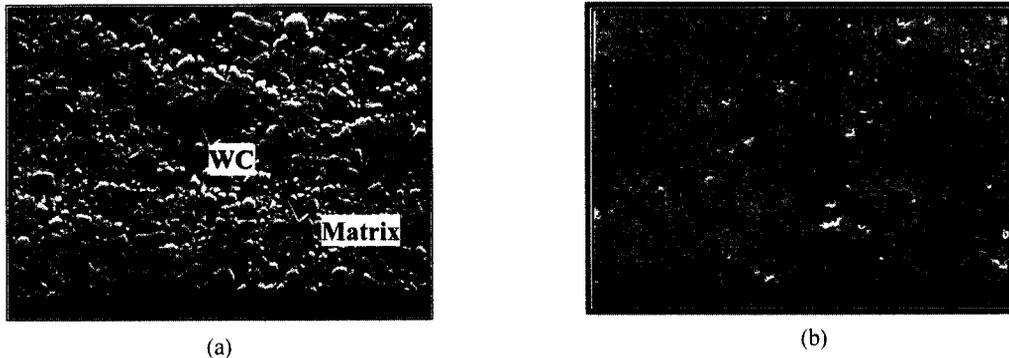


Fig. 2. Microstructures of WC-Co (a), WC-CrNi (b) coatings.

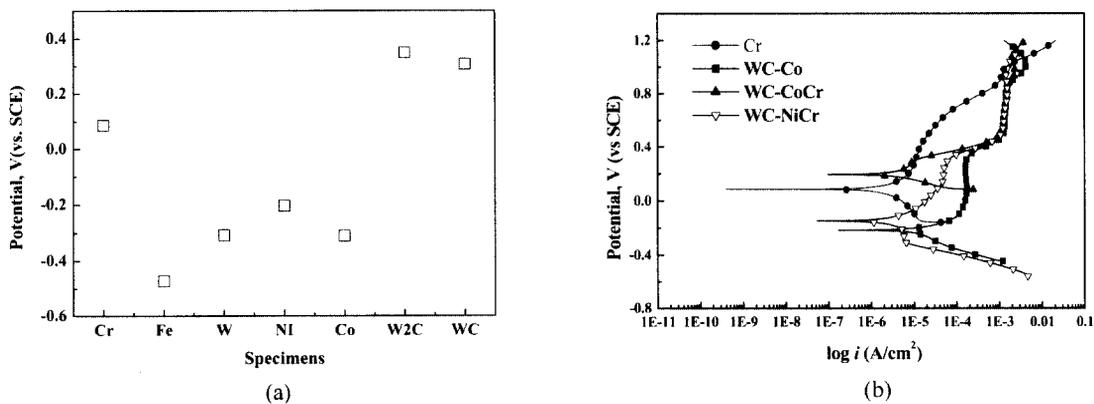


Fig. 3. Electrochemical behaviors of WC cermet coatings. (a) Free potential measured of component (b) Polarization scan of WC cermet coatings.

3.2 Immersion test

In the visual observation of coating surface after immersion in pH 0.3 solution for 7 days binder matrix obviously dissolved leaving only WC particles for WC-Co (Fig. 4 (A)). WC is chemically more stable than cobalt in acid solution and corrosion progresses by oxidation of binder, leaving only WC particles. WC-CrNi shows little change of surface (Fig. 4 (B)) but substrate heavily attacked and spalled off coating layer from substrate (Fig. 5). Galvanic corrosion of coating/substrate is a result of the porous structure of sprayed coatings and occurs when pores are connected all the way down to the substrate. Steel substrate protected coatings cathodically while more noble stainless steel substrate had almost the same corrosion potential in compared of the coatings. In case of WC-CrNi coating, Cr_2C_3 shows no binder effect, only 7% Ni play role of binder. The reduction of the amount of metallic binder in nature occurred high porosity level in coating layer. In Fig. 6 SVET data, steel substrate shows galvanic effect (anodic current on steel substrate, cathodic current on coating layer) and the STS 316 substrate shows almost no current activity difference for WC-CrNi in solution.

3.3 Corrosion-wear test

Friction coefficient may depend on corrosion properties of coatings. In acidic solution, coatings with a less corroding binder shows high friction coefficient than a coating with high corroding binders (Fig. 7). This is reasonable since coating has a highly corroding binder spalled off WC particles and corrosion product may act like lubricant in coating surface. For WC-CrNi surface of tested specimen show little worn out and many cracks are in Cr coating plate (Fig. 8).

4. Conclusions

- 1) The corrosion of WC-Co coating ascribed to Co binder corroded actively then binder around WC particles is removed making WC particles fall out easily in acid solution.
- 2) WC-CrNi coating showed good corrosion and corrosion-wear properties, but when sprayed with steel substrate, porosity of coating layer play a more important role in service life
- 3) WC-CrNi coating sprayed with STS 316 substrate

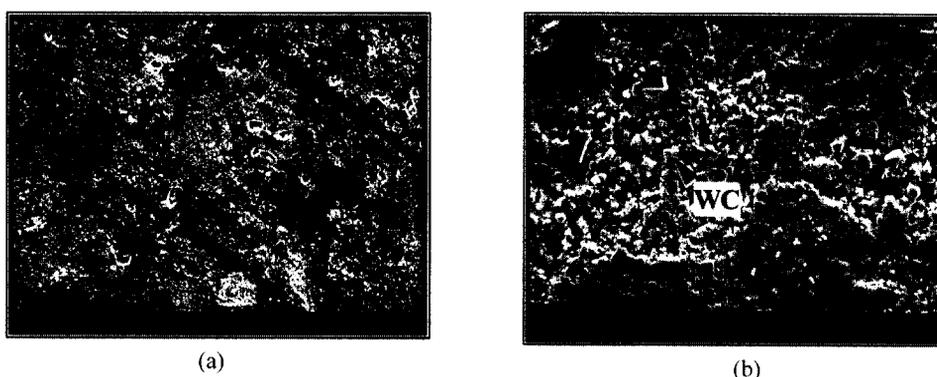


Fig. 4. WC cermet coatings surfaces after 7 days immersion in pH 0.3 solution. (a) WC-Co (b) WC-CrNi

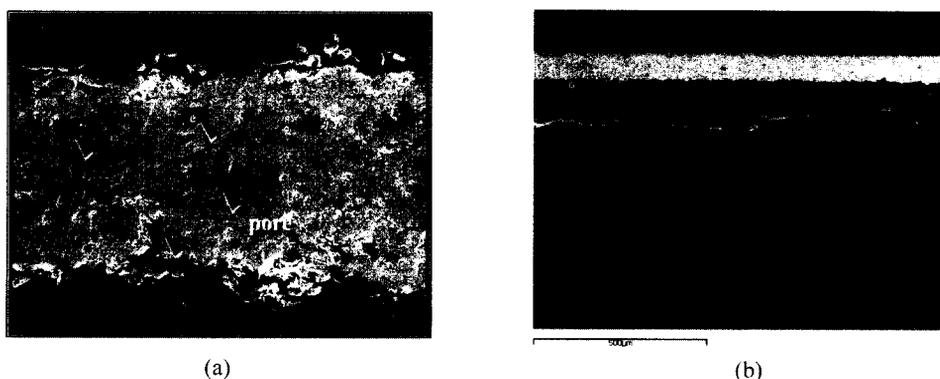


Fig. 5. Micro-pores and galvanic corrosion of coating/substrate for WC-CrNi coating. (a) pores in coating layer (b) Corrosion of coating/substrate interfacial after immersion test.

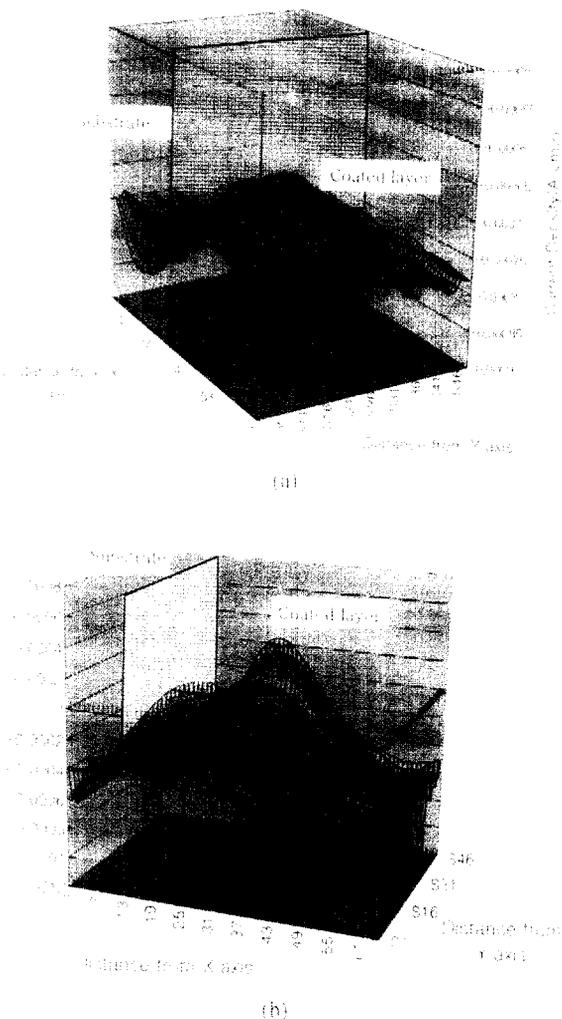


Fig. 6. 3-D current density map of cross section coating/substrate interface area. (X and Y axis represent location of area while the Z axis represent current density). (a) coated layer : WC-NiCr, substrate : STS 316 (b) coated layer : WC-NiCr, substrate : carbon steel.

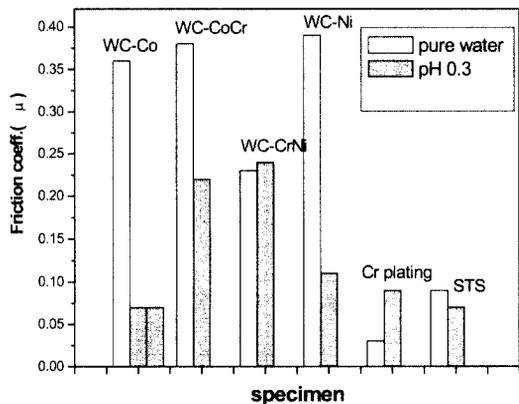
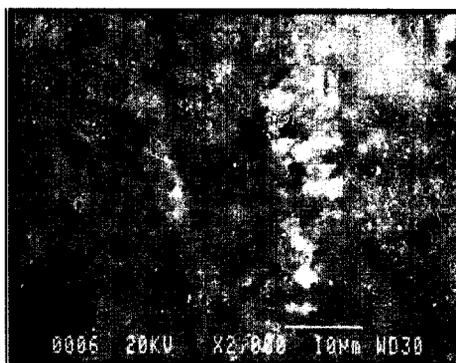


Fig. 7. Friction coefficients of WC coatings in acid and pure water.



(a)



(b)

Fig. 8. Surface of coating specimen after corrosion-wear test. (a) WC-CrNi (b) Hard Cr coating plate

will become an important improvement when coated components are used in acid solution.

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