A comparative study on corrosion behavior of WC-CoCr and WC-CrC-Ni coatings by HVOF

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초 록: High velocity oxy-fuel (HVOF) thermal spraying coating has been used widely throughout the last 60 years mainly in defense, aerospace, and power plants. Recently this coating technique is considered as a promising candidate for the replacement of the traditional electrolytic hard chrome plating (EHC) which pollutes the environment and causes lung cancer by toxic hexa-valent Cr^{6+}. In this study, two kinds of cermet coatings, WC-CoCr and WC-CrC-Ni, are formed by HVOF spraying. The corrosion and electrochemical properties are evaluated by polarization tests in 3.5 wt% solutions.

1. 서 론

Electrolytic hard chrome (EHC) has been extensively used for many years in applications that require wear and corroion resistance, such as hydraulic cylinders, rotating shafts, aircraft landing gears, valves, rolls and machines tools. However, the toxicity of the galvanic bath and the hex valence chromium (Cr^{6+}) are environmental problems leading to high waste-disposal costs. Furthermore, the often required post-plate baking and if necessary, the grinding of an unevenly thick chrome layer also add to the cost. Additional disadvantages are the micro-crack network due to large internal tensile stresses, the low deposition rates and the limited corrosion protection of the substrate.

Recently, high velocity oxy-fuel (HVOF) thermal spraying technique is considered as a promising candidate for the replacement of EHC. Typically, WC-Co coating is used due to its excellent wear resistance. However, this coating has lower corrosion resistance as compared to other cermet coatings. Therefore, more studies into other cermets coatings have been carried out [1-2]. In addition, to satisfy a specific set of requirements, an in-depth knowledge of the various coatings' properties and performance is essential.

In this paper two kinds of cermet coatings, WC-CoCr and WC-CrC-Ni, are formed by HVOF spraying. The corrosion and electrochemical properties are evaluated by polarization tests in 3.5 wt% NaCl solutions.

2. 본 론

2.1 Experiment

The electrochemical experiments are carried out by Gamry Instrument (USA/CMS 1058) and a three electrode corrosion cell (shown in Fig. 1). Polarization tests are carried out for the as-sprayed coatings in different corrosion solution such as 3.5 wt% NaCl solutions respectively at room temperature. The surfaces of all coatings are polished by using SiC emery paper from 180-grit to 1200-grit grades gradually and then using diamond paste until 1 μm. The polished samples are cleaned with ethanol in an ultrasonic washer

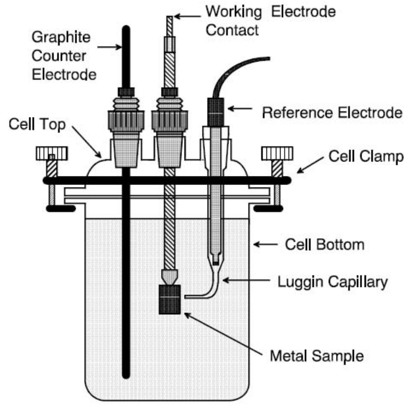

Fig.1 Three electrode corrosion cell used in electrochemical experiment

and an area of 1.1 cm^2 is exposed to

corrosion solution. A saturated calomel electrode (SCE) is used as the reference electrode, and a graphite rod served as the counter electrode for current measurement. The potential is increased from −0.5 V to 1.5 V vs. open circuit potential with a scanning rate of 5 mV/s. The surface morphologies and cross−section images The corrosion potentials (E_{corr}) of all coatings which show the susceptibility to corrosion are recorded according to the polarization curves. The corrosion densities (I_{corr}) which reveal the protective ability of coatings to corrosion attack are calculated by Tafel extrapolation method[3]. The surface morphologies of coatings after electrochemical tests are observed by OM to give more information about corrosion mechanism.

2.2 Results and Discussion

Fig. 2 shows the polarization curve of coatings exposed in the 3.5% NaCl solution. When the applied potential is increased from -0.5 V to 1.5 V gradually, it can be observed that passivity does not happen for two coatings in thissolution. This phenomenon is difference from the typical behavior of pure metal (for example, chrome) which may be attributed the characteristics of ceramet.

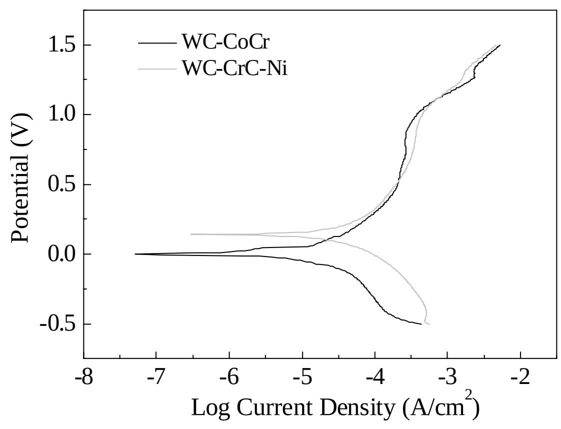

Fig. 2 Polarization curves of WC−CoCr and WC−CrC−Ni in 3.5 % NaCl solution (wt %)

Fig. 3 exhibits the OM images of corrodedsurfaces with the different magnification times. The microstructures of coatings which are just similar to the surface endured through chemical etching can be seen clearly. It indicates that the WC−CoCr and WC−CrC−Ni coatings have undergone general corrosion due to the absence of localized pits [4]. Besides, the digi−micrograph demonstrates no three−dimensional solid film or absorptive film have formed on surface.

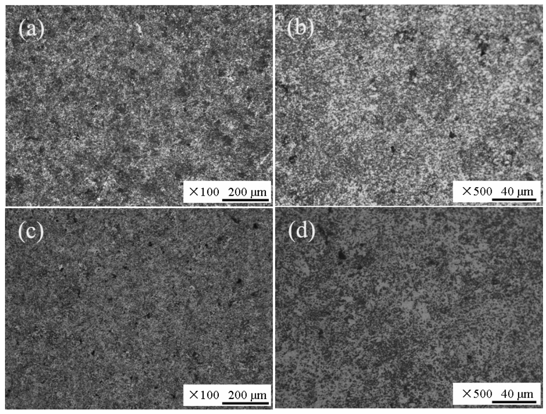

Fig. 3 OM images of the corroded surfaces. a) and b) are WC−CoCr coating, c) and d) are WC−CrC−Ni coating.

Table 1 shows the corrosion potential (E_{corr}) and corrosion current densities (I_{corr}) in 3.5% NaCl. WC−CoCr has more active E_{corr} than WC−CrC−Ni coating. The results indicate that WC−CrC−Ni is less susceptible to corrosion probably due to the metallic matrix including nickel [3]. However, on the other side, WC−CoCr is more protective to corrosion because the I_{corr} is smaller than that of WC−CrC−Ni.

Table 1 Corrosion potential and corrosion current density of WC−CoCr and WC−CrC−Ni coatings in different solutions (Unit of E_{corr} is V; I_{corr} is μA/cm^2)

Solution / Powder	NaCl		HCl		NaOH	
	E_{corr}	I_{corr}	E_{corr}	I_{corr}	E_{corr}	I_{corr}
WC-CoCr	0	15.087	0.08	144.081	-0.4	28.748
WC-CrC-Ni	0.18	34.563	0.2	1020.017	-0.25	9.091

3. 결론

The coatings suffer uniform corrosion in 3.5% NaCl but localized corrosion in 1 M HCl. In 1 M NaOH, the coatings are covered by protective films because of occurrence of quasi−passivation.

In 3.5% NaCl WC−CoCr coating is more protective than WC−CrC−Ni coating due to less interfaces between WC phases and metallic binder matrix, more homogeneous microstructure, less porosity and more cobalt content.

감 사 의 글

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참 고 문 헌

[1] B. R. Marple et al., Tungsten carbide based coatings as alternatives to electrodeposited hard chrome, Proceedings of UTSC'99, Dusseldorf, Germany, 17-19 March 1999, DVS, 123-127 (1999).

[2] U. Erning et al., HVOF coatings for hard-chrome replacement - properties and applications, Proceedings of UTSC'99, Dusseldorf, Germany, 17-19 March 1999, DVS, 462-467 (1999).

[3] P. K. Aw et al., , Thin Solid Films, in press, (2007).

[4] Devicharan Chidambaram et al., Surface & Coatings Technology, 192, 278-283, (2005).[