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Sensitivity Analysis of Immersion Corrosion Parameters in WC–10CO–4Cr Coated Brass Alloy for Extended Surfaces

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ABSTRACT: The HVOF sprayed WC-CO-Cr cermet coatings has widely attracted coatings over the lower corrosion resistance materials, to improve the corrosion resistance for extended surfaces. The corrosion rate of WC-CO-Cr coatings will be affected by the immersion corrosion parameters, such as pH value, immersion time, and Chloride ion concentration. The response surface methodology was used to develop the empirical relationship to predict corrosion rate of the WC-CO-Cr coatings over the brass alloy incorporating immersion corrosion parameters. It is found that the corrosion rate decreases with the increase of pH value and immersion time, and increasing the cl ion concentration the corrosion rate also increased, but the initial increase of cl ion concentration increases the corrosion rate and further increase of cl ion concentration does not corrosion rate. Sensitivity analysis was also carried out to understand the impact of each immersion corrosion parameters on WC-CO-Cr coatings over the brass alloy.

KEYWORDS: Corrosion, Thermal spray, Sensitivity. Extended surfaces

I. INTRODUCTION

Corrosion is major problem in different industry segments such as the aerospace, biomedical, resources, power, and marine environments. The detriments in the mechanical properties or the waste of raw materials are among the most important consequences of the corrosion. During the last decades, vast effort has been made to understand corrosion phenomena and mechanisms, and to elucidate the leading cause that influences the service lifetime of materials, particularly metals. The properties of metal materials in aggressive environments are critical for a sustainable society and result not only from microstructures and physico-chemical characteristics, but also from the performance of their surfaces. Therefore, there is significant ongoing research in this area seeking to improve the surface properties, ranging from development of anti-corrosion coatings over the materials toselection of better surface treatment technologies [1]. The overall life-time impact of thermal spray process on health and Environments are generally much lower than EHC, the HVOF thermal spraying process has shown to be one of the best alternatives for chrome replacement because it produces low porosity (<1%), low oxide content (<1%) and highly adherent (bond strength > 70 MPa) coatings.The corrosion performance of HVOF-sprayed WC-Co-Crcoatings is complex because of their multiphase microstructure, which involves various corrosion cell inducers, such as interlayer boundaries, pores, phase boundaries, oxide inclusions and non-uniform carbide dissolution into the metal matrix. These micro structural features deeply affect the corrosion mechanisms. Several authors have shown that a sequence of corrosion reactions occurring on the metal binder, at the interface between the binder and the ceramic hard phase and on the hard phase itself all give to the corrosion degradation. Furthermore, if the coating has been poorly deposited, it may possess some interconnected porosity. The absence of pores and cracks (micro and macro) is very important when corrosion resistance is required because the electrolyte can penetrate through these defects to reach the substrate[2]. Hence, the present work was carried out to

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develop an empirical relationship to predict the corrosion rate of HVOF sprayed WC-Co-Cr coatings on brass alloy under immersion environment, and the sensitivity analysis also carried out to understand the impact of each immersion corrosion parameters on WC-CO-Cr coatings over the brassalloy [3-5]. The types of extended surface shown in fig 1.

Fig 1: Types of extended surface

II. EXPERIMENTAL WORK

In this investigation, commercial grade copper-basedbrass a high good corrosion resistance material having greater strength and rigidity was used. The coating powder material used in this investigation was commercially available agglomerated and sintered WC-Co-Cr and the chemical composition of brass substrate conforming to specification ASTM B171. The chemical composition of Brass and WC-Co-Cr was used.HVOF spraying system was used to deposit WC-10Co-4Cr coatings with a thickness of 180-200 µm. The thickness of the coatings was measured by digital micrometer (with an accuracy of 0.001mm) after each and every run conditions. The WC-Co-Cr coated brass was used for this investigation.WC-Co-Cr coated brass specimens are shown in Fig. 2.The specimens were cut into the dimensions of 16 x 15 x 4 mm to evaluate the corrosion rate by immersion corrosion test methods. The specimens were ground with 500#, 800# and 1200#, 1500# grit SiC paper washed with distilled water and dried by warm flowing air before the corrosion experiment was carried out. The coatings were developed under optimized HVOF spray parameters.Immersion corrosion test was performed in artificial seawater prepared with deionized water and sea salt. This acid preparation consisted of an ultrasonic 50 vol. % NaCl and 50 vol. % H_2O.After the prescribed period of immersion described in the experimental condition, the specimens were taken out and the weight loss was measured. Corrosion rate was determined by using the formula as given below, in which K is a constant that depends on the desired units. For a corrosion rate in mm/year, $K = 8.76 \times 10^4$ [5-7].

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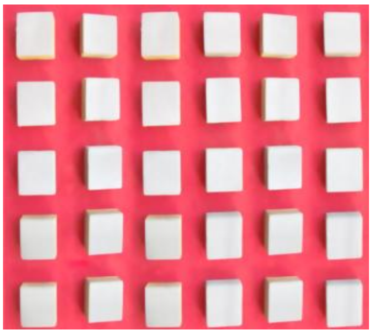

Fig. 2HVOF sprayed WC-Co-Cr coated brass

$$\text{Corrosion rate} = \frac{\text{Weight loss(g)X K}}{\text{Alloy density}\left({}^{g}/_{cm3}\right)\text{x Exposed area(cm2) X Exposure time(h)}}$$

III. RESULTS AND DISCUSSION

From the literature [8], and the previous investigation carried out in our laboratory the predominant factors that have a greater influence on the corrosion behavior

Table 1Corrosion test experimental parameters and their levels

S. No.	Factor	Unit	Levels				
			−2	−1	0	1	2
1	pH value	pH	2	4	6	8	10
2	Exposure time	hours (h)	48	72	108	144	168
3	Cl^{-} concentration	Mole (M)	0.2	0.4	0.6	0.8	1

were identified. They are: (i) pH value of the solution, (ii) chloride ion concentration and (iii) exposure time. In present study, RSM using central composite design was applied with full replication technique. Based on the experimental results, four predominant variables namely, pH value, immersion time, Cl- ion concentration, was selected. For recording the responses due to changes in these variables, every selected variable was operated at five different levels (−1.68, −1, 0, 1, 1.68) and the values of these variables corresponding to these levels are shown in table. 1.

3.1 Developing empirical relationships to predict corrosion rate

In order to determine the optimum levels of the process variables studied and their relationships, RSM concept was employed. RSM is a combination of mathematical and statistical techniques that are generally used for DOE, development of a mathematical model, identification of optimum combination of input parameters, and graphical expression of results for better understanding. The relationship between the variables and the response after analysis was determined using the second order polynomial equation.

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$$Y = \beta 0 + \beta iXi + \sum \beta iiXi^2 + \sum \beta ijXiXj$$

The Corrosion Rate of the HVOF sprayed coatings are functions of pH value (P), immersion time (T), Cl-concentration(C), and it can be expressed as

Corrosion rate CR = f {P, T, C}

The empirical relationship for corrosion rate chosen includes the effects of the main and interaction effects of all factors. The construction of empirical relationship and the procedure to calculate the values of the regression coefficients can be referred elsewhere. In this work, the regression coefficients were calculated with the help of Design Expert V 12.1 statistical software.After determining the coefficients (at a 95% confidence level), the final empirical relationship was developed using these the final empirical relationship to estimate the corrosion rate in mm/yr. is given below:

$$CR=2.06 - 0.74 (P) – 0.62 (T) + 0.26 (C) + 0.33 (PT) + 0.23 (PC) -0.37 (TC) + 0.36 (P)^2+0.02 (T)^2-0.02 (C)^2 \text{ mm/yr.} \quad (1)$$

3.2 SENSITIVITY ANALYSIS

Sensitivity analysis is an important tool to quantify the influence of input corrosion parameters on the output response. This type of analysis can also be used to control the input parameters during corrosion experiments as if they are more sensitive on output response. [10] mathematically, sensitivity of an objective function with respect to a design variable is the partial derivative of that function with respect to its variables.

$\partial CR/\partial P$ = -0.74+0.33(T) +0.23(C) +0.72(P) (2)

$\partial CR/\partial P$ = -0.62+0.33(P)-0.37(C) +0.04(T) (3)

$\partial CR/\partial C$ = 0.26+0.23(P)-0.39(T)-0.04(C) (4)

The sensitivity Eqs. 2,3and 4 represent the sensitivity on corrosion rate for pH value, immersion time, and Chloride ion concentration, respectively. Sensitivity is analyzed here using the partial derivatives of Eqs. 2 through 4. Namely, positive sensitivity values imply an increment in the objective function by a small change in design parameter, whereas negative values state the opposite. To evaluate sensitivities, each input corrosion experiment parameter should be varied while keeping all other input parameters constant to see how the output parameters react to these variations. An output parameter would be considered very sensitive with respect to a certain input parameter if a large change of the output parameter value is observed. Sensitivities of process parameters on corrosion rate are presented. Figure 3 (a–c) shows the sensitivity of corrosion rate for the primary factors pH value, immersion time, and Chloride ion concentration respectively on corrosion rate.Considering the changes of corrosion rate, the sensitivity of immersion corrosion parameters can be ranked as follows: the pH value is more sensitive followed by immersion time and Chloride ion concentration respectively. The fig 3 shows the sensitivity graphs.

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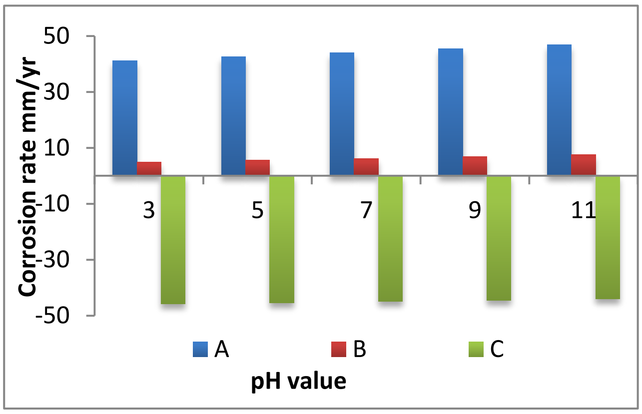

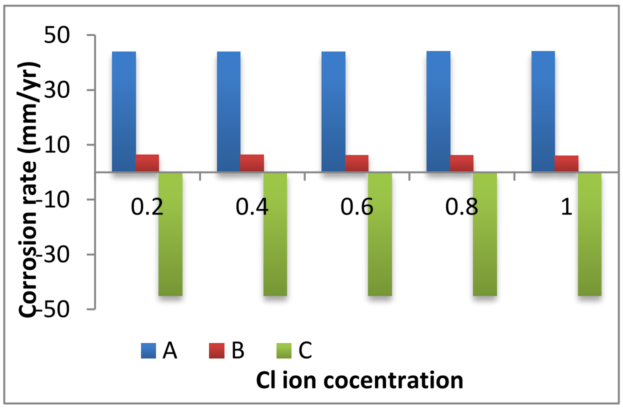

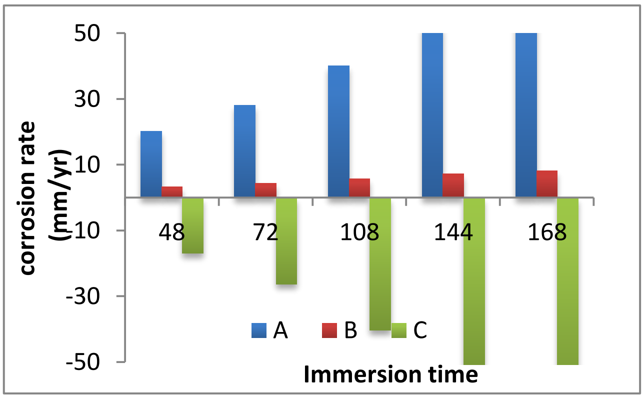

IV. CONCLUSION

From the investigation of WC-Co-Cr coated brass alloy, the following conclusions were obtained:

1. Empirical relationship for finding the corrosion rate of WC-Co-Cr coated brass was established incorporating with the pH value, exposure time and chloride ion concentration for immersions conditions the developed relationship can be effectively used to predict the corrosion rate of WC-Co-Cr coated brass alloy at 95% confidence level.
2. In WC-Co-Cr coated brass, the highest corrosion rate was observed at lower pH value. The corrosion rate was higher in the acidic media than in alkaline and neutral media.
3. The WC-Co-Cr coated brass alloy specimens were lower corrosion rate the immersion environment. Thus, the specimens proved to give a long life from corrosion in marine environments.
4. From the sensitivity analysis, it is found that the pH value is the most sensitive immersion Corrosion parameter followed by immersion time andChloride ion concentration.

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