Investigating Corrosion of Low Alloy Steel Detection Method based on Wire Beam Electrode

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Abstract. A wire beam electrode (WBE) method for investigating the local corrosion has been demonstrated by mapping non-unifore corrosion processes occurring on low alloy steel in solution of H3BO3 concentrations. It was found that low alloy steel from the sporadic points at the beginning of the test, the local corrosion range is the largest when it develops for 24 h and obvious local corrosion appeared, then it decreases when it reaches 48 h. To sum up, it is feasible to study the behaviors of low alloy steel localized corrosion with WBE.

Keywords: corrosion, WBE, low alloy steel, detection method.

1. Introduction

Low alloy steel plays a crucial role in modern industry and widely applied in nuclear power plant pressure vessels, regulators, containment and other shell materials because of its excellent formability and weldability, high strength, good resistance to corrosion. In view of its excellent characterize, they are unavoidably applied to some extreme environments with high temperatures, high pressure, and high radiation. With the development of the nuclear power plant reactor, some corrosion problems which are found constantly have a serious impact on the safety service of nuclear power plant [1-3]. Therefore, much research on the corrosion of low alloy steel in relevant aqueous solution has also attracted the attention of international scholars. T. Yongjun et al. [4] evaluated the crevice corrosion sensitivity of carbon steel in different atmospheres by using the WBE technique. To our knowledge, it is feasible for low alloy steel to employ the WBE method under relevant aqueous solutions environment and can provide a new idea for studying the corrosion behavor of low alloy steel at different conditions.

2. Experimental

This paper reports on a study of the effect of H_3BO_3 concentrations in the PWR primary water accident on the localized corrosion of low alloy steel SA738, using the WBE analysis methods, X-ray diffraction. All experiments were carried out at room temperature and at atmospheric pressure.

The experimental materials included the low alloy steel SA738 was mainly produced by a domestic steel plant and the chemical composition (wt. %) of the steel was shown in Table I.

Table II presents the compositions of the solution, which was designated as solution A. Throughout the text, adding B means adding H_3BO_3, and adding Li means adding $LiOH \cdot H_2O$.

Table 1. Chemical Compositi of Sa738 Low Alloy Steel (Mass Fraction, %)

Steel	C	Si	Mn	P	S	Cr	Ni	Cu	Mo	Nb+V	Fe
SA738	0.09	0.2	1.4	0.0038	0.0011	0.02	0.37	0.1	0.2	0.065	Bal

Table 2. Composition and Ph of Solution

Solution	B as H_3BO_3 (wt ppm)	Li as LiOH (wt ppm)	pH
Solution A	1200	2	6.4

The wire beam electrode (WBE) consisted of 100 microelectrodes, each of which was made from SA738 low alloy steel with a diameter of 1(mm) and a length of 30 (mm). The electrochemical measurements were constructed by the wire electrode potential current scanner CST520 and electrochemical workstation CS350. The working surface of the WBE was immersed in the H_3BO_3 concentration solution for testing at room temperature in this paper. The wires were insulated from each other and assembled in a customized mold shown in Fig. 1 with an interval of 1 (mm), then the epoxy resin was used for pouring and sealing. The total effective working electrode area (the area exposed by these wires) was about 1 (cm^2).

Figure 1. Schematic diagram of CUSTOMIZED MOLD

3. Results and Discussion

3.1 Wire beam electrode test results

In order to research the action effects of H_3BO_3 concentration for low alloy steel in oxygen-contained solutions, the corrosion potential and galvanic current distribution map was measured by WBE. The measurement date was used to evaluate the localized corrosion degrees of the steel in different kinds of solutions.

Fig. 2 presented the changes of potential and current distribution maps of the WBE immersed in solution A as a function of time at 25 (℃) temperature environments. An apparent phenomenon discovered that the corrosion potential and galvanic current distribution maps was mutually corresponding, and mainly showing localized corrosion. The probable initiation sites of localized corrosion were caused by the presence of active substances such as impurities and defects on the steel surface [5]. During the initial period of immersion, the corrosion initiation occurred at the column 10, row 5, the column 3, row 3, the column 2, row 5, the column 1, row 5, and the minimum value was -0.41592 (V), and the anodic and cathodic current distribution were obviously appeared numerical differences from the color and the scale, showed that the beginning of corrosion was a stochastic process, as shown in Fig. 3(a1) and (a2). With the propagation of the corrosion, it can be seen that the corrosion potential became more negative and the value was -0.58393 (V). The WBE surface gradually increased anodic area and decreased of the cathodic area were speculatively caused by potential difference, which meant that low alloy steel material in this area has a poor corrosion resistance. After immersed in solution A for 24 (h), a large of anodic corrosion area gradually occurred around the original point corrosion, and the maximum corrosion current value was about 2.82E-07 ($A \cdot cm^{-2}$). While further increasing the soaking time to 48h, it was evidently found that the WBE surface corrosion degree appeared smaller than immersing for 24 (h). Compared with the maximum anode current of different soaking time, the value of the maximum anode current was gradually increased and then decreased, and the maximum value was 1.85E-05 ($A \cdot cm^{-2}$) appeared in immersing 12 h.

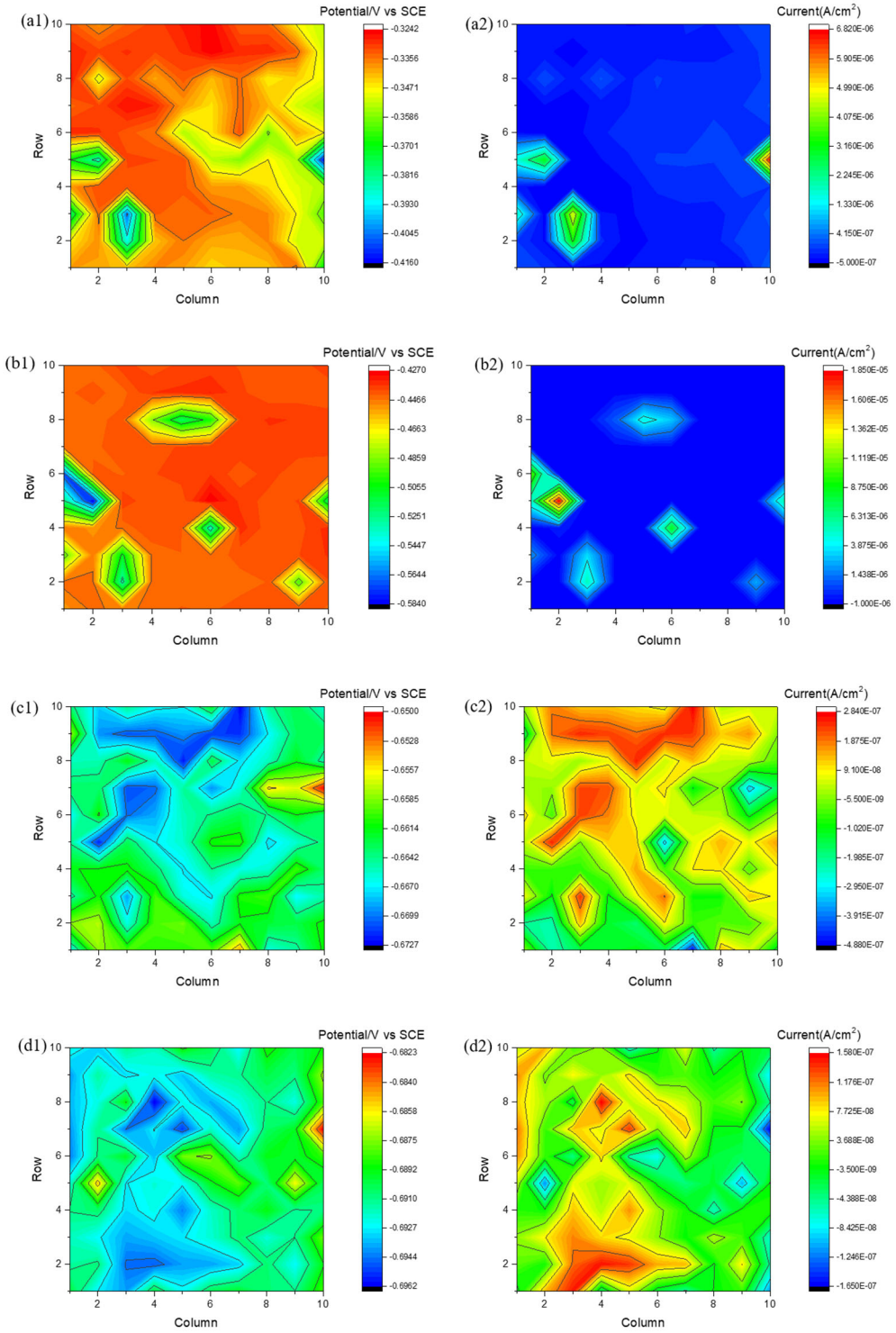

Figure 2. CORROSION POTENTIAL, GALVANIC CURRENT DISTRIBUTION distribution maps from the WBE immersed in solution A for 48 h. (a1) 0 h potential; (a2) 0 h current; (b1) 12 h potential; (b2) 12 h current; (c1) 24 h potential; (c2) 24 h current; (d1) 48 h potential; (d2) 48h current

3.2 The analysis of X-ray diffraction (XRD) to corrosion products

Fig. 3 showed the XRD patterns of the surface of the tested steels before and after the EIS measurement which was measured conducted after 0.5 (h) immersion in solution A. The diffraction peaks of specimens are Ni-Cr-Fe phase, which is the main matrix phe both in the before and after corroding steels. On the other hand, the peaks found at 2θ=14.2°, 27.3° and 36.4° found only in the

eroded steel in XRD spectra are attributed to the presence of FeO(OH) on the surface. The previous study has reported that in aerated near-neutral to acid conditions, ferrous ions are oxidized by dissolved oxygen in solution, and the corrosion products are FeO(OH). The results are consistent with those reported for the corrosion products of low alloy steel in the boric acid environment.

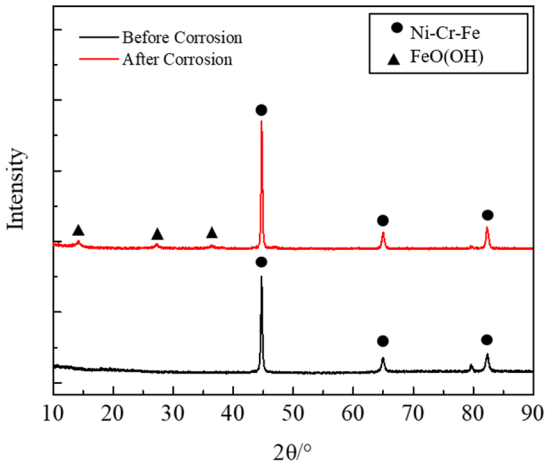

Figure 3. XRD spectra of the tested steel between matrix and corrosion

4. Conclusion

The corrosion behaviors of the low alloy steel in the solution A were investigated. With the increase of testing time to 24 (h), the results indicated that the anodic area of WBE surface gradually increases and the cathodic area gradually decreases in the local corrosion area of low alloy steel, indicating that the corrosion resistance of low alloy steel materials in this area is poor and the XRD test results can also provide good evidence. Meanwhile, compared with the maximum anode current of different immersion times, the maximum anode current value showed a trend of first rising and then declining, and reached the maximum value at 12 (h) immersion.

To sum up, the WBE method applied in corrosion research is feasible for evaluation of local corrosion behaviors of low alloy steel in complex environment.

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