Spectral Analysis of Electrochemical Noise Generated during a Stress Corrosion Cracking of Inconel Alloys for a Steam Generator Tubing in a PWR

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1. Introduction

As many authors have reported on a fluctuation of the electrochemical potential and current associated with localized corrosions such as a pitting, crevice corrosion and stress corrosion cracking (SCC) in experimental data [1], an electrochemical noise (EN) measurement has become a useful technique for monitoring these localized corrosions of steam generator (SG) tubing materials in pressurized water reactors (PWR) [2]. Moreover, it was also reported that this technique is powerful enough to distinguish between the initiation and propagation of SCC based on a stochastic theory [3].

The purpose of this study is to investigate the initiation and the propagation processes of a SCC of Inconel alloys such as 600 and 690 for SG tubes by a spectral analysis of the EN data.

2. Experimental

Alloy 600 (HTMA, HTMA + Sensitization, TT, SA + Sensitization) and alloy 690 (TT, SA + Sensitization) SG tubes were used. The C-ring specimens were manufactured from the heat-treated alloy 600 and 690 tubes according to ASTM G38. The outer diameter surface of a specimen was ground by #1200 emery paper and cleaned with methanol and water in sequence. The working electrode was the specimen stressed to 150% of its room temperature yield strength using alloy 600 bolts and nuts. And the counter electrode was the unstressed specimen.

EN measurements were carried out with a Zahner IM6e equipped with a Zahner NProbe. Electrochemical potential noise (EPN) and current noise (ECN) were recorded in a 0.1M $Na_2S_4O_6$ solution at room temperature. After an entire immersion test, the specimens were polished and chemically etched with a bromine solution (2% bromine + 98% methanol), and then they were examined by an optical microscope (OM) and stereo-microscope (SM).

3. Results and discussion

3.1. Microstructure analysis

From the OM analysis of the C-ring specimens after the entire immersion test in a 0.1M $Na_2S_4O_6$ solution, it was observed that a SCC was propagated in an intergranular (IG) mode. Fig.1(a) shows the SM image of the outer diameter surface of the sensitized alloy 600 HTMA, and Fig.1(b) shows the OM image of the cross section of its apex.

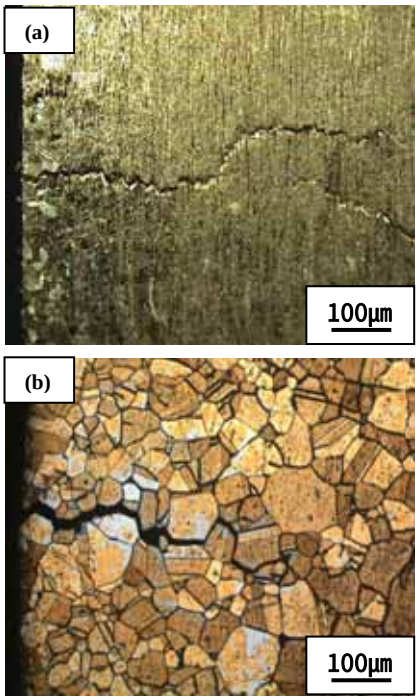

Fig. 1. (a) SM image of the outer diameter surface, (b) OM image of the cross section of the apex of the sensitized alloy 600 HTMA C-ring specimen after the entire immersion test in a 0.1M $Na_2S_4O_6$ solution at room temperature.

3.2. Electrochemical noise analysis

Fig. 2 presents the plots of the power spectral density (PSD) vs. the frequency calculated by a fast Fourier transformation (FFT) algorithm from time records of the EPN and ECN measured from the sensitized alloy 600 HTMA. It is clearly seen that the PSD obtained at point B, where both EPN and ECN reveal an increase of the fluctuation due to SCC, is higher than that obtained at points A and C, where both EPN and ECN exhibit a typical behavior corresponding to a uniform corrosion. The increase in the value of the PSD is remarkable at a low-frequency region in Fig. 2(a) and (b), which strongly indicates an increase in the number of localized corrosion events, that is, the initiation and propagation of a SCC [2, 3].

The PSD measured from various SG tubing materials will be analyzed and discussed in detail in terms of the SCC susceptibility of those materials.

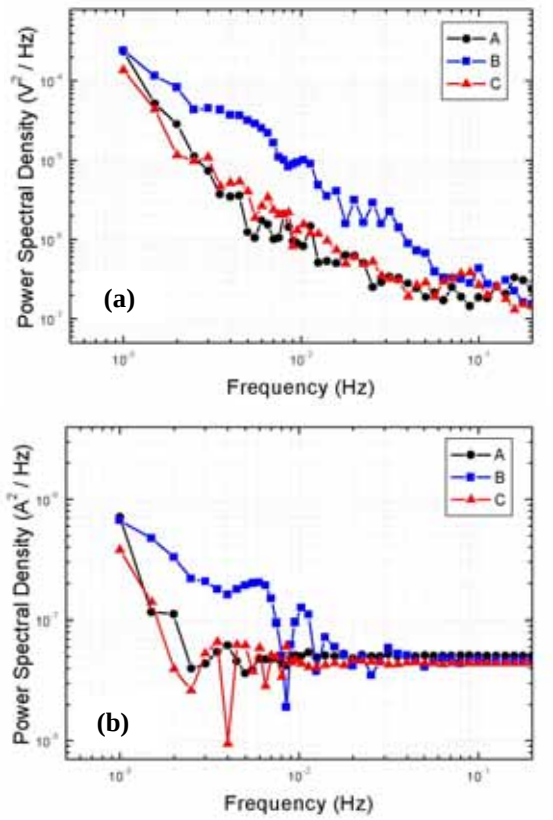

Fig. 2. Plots of the power spectral density (PSD) vs. the frequency calculated by FFT algorithm from time records of (a) EPN and (b) ECN measured on the sensitized Alloy 600 HTMA specimen in a 0.1M $Na_2S_4O_6$ solution at room temperature.

4. Conclusion

From the spectral analysis of the EPN and ECN obtained from Inconel alloys such as 600 and 690 with various heat-treatments in a 0.1M $Na_2S_4O_6$ solution at room temperature, it was observed that the increase of both EPN and ECN is strongly correlated with the initiation and propagation of a SCC.

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