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A Review of Application of Electrochemical Noise Monitoring to Light Water Reactor Systems

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1. Introduction

Over the past many years, electrochemical noise (EN) has been one of the most versatile corrosion monitoring and measurement techniques to emerge from the research laboratory and to be employed at operating plants by a number of workers [1-4]. For corrosion monitoring purpose, the momentary changes in the corrosion potential of a test specimen are measured with respect either to a thermodynamically stable reference electrode or, more commonly, to a quasi reference electrode of suitable material and design [5]. The principal objectives of the present work were to demonstrate the feasibility of using EN techniques SCC initiation in a representative light water reactor (LWR) environment and to investigate the possibility of developing an in-reactor EN sensor on the basis of a blunt notch, CT specimen.

2. Methods

2.1 Materials, Specimens, and Mechanical Testing

Slow strain rate test (SSRT) experiments utilized commercial heat 71635 of Type 304 stainless steel which was solution annealed at 1050°C for 30 minutes and water quenched, then sensitized at 621°C for 24 hours. All SSRT experiments were performed using an Instron 1130 tensile testing machine. After the feasibility of monitoring the onset of stress corrosion cracking by electrochemical noise was established on the SSRT test specimens, two tests were performed on 1-inch compact tension (1T CT) specimens to evaluate the use of electrochemical noise for detecting both crack initiation and growth in a very different specimen geometry. Tests on the 1T CT specimens utilized a commercial heat of Type 304 stainless steel which was solution annealed at either 1100°C for 1 hour (specimen SA-1) or 1050°C for 30 minutes (specimen SA-2) followed by water quenching; sensitization performed at 621°C for 24 hours [6]. Both CT tests were performed in the same fully instrumented 4-liter autoclave system.

2.2 Procedures: SSRT Tests and CT tests

Table 1 summarizes the experimental variables for the sequence of SSRT tests. Electrochemical control and monitoring instruments maintained the room temperature conductivity of the water at 0.27μS/cm with minute additions of H_2SO_4, and kept the autoclave temperature at 288°C with a flow rate of 75cc/min and a system pressure of 10.4 MPa.

Table 1: Experimental Variables in SSRT Tests

Test No.	Test condition	External noise	WE1/masking	RE	WE2
#1	NWC Straining-failure	A/C on	Smooth gage No coating	Ag/AgCl	Autoclave
#2	NWC Straining-interruptions-failure	A/C on	Smooth gage No coating	Ag/AgCl or SS spiral	Autoclave or SS spiral
#3	HWC/NWC/HWC Straining-interruptions-failure	ZRA-in/out/in A/C on	Smooth gage No coating	Ag/AgCl or SS spiral	Autoclave or SS spiral
#4	NWC Straining-interruptions-failure	A/C on	Notched No coating	Ag/AgCl or Pt spiral	Autoclave or SS spiral
#5	HWC/NWC/HWC Straining-stopped-failure	A/C on	Notched No coating	Pt spiral	Autoclave or SS spiral
#6	NWC Straining-interruptions-stopped before-failure	ZRA-in/out/in A/C on/off cycles	Notched No coating	Pt spiral	SS spiral
#7	NWC Straining-interruptions-failure	A/C off	Smooth gage ZrO_2 coating Outside gage length	Pt spiral	SS spiral
#8	NWC Straining-stopped pre-failure	A/C on, shield for load frame	ZrO_2 coating over entire surface	Pt spiral	SS spiral
#9	NWC Straining-stopped pre-failure	A/C on, shield for load frame	Smooth gage No coating	Pt spiral	SS spiral
#10	NWC Straining-stopped pre-failure	A/C on, shield for load frame	Smooth gage No coating	Pt spiral	SS spiral

3. Results and discussion

For laboratory SSRT tests in LWR environments, the standard deviation of the potential gave an effective, real-time indication of IGSCC. A Pt wire in close proximity to the susceptible gage section surface, or directly adjacent to the target site (notch), was the most effective reference electrode. Zirconia shielding was unnecessary with local auxiliary electrodes, and actually appeared to contribute extraneous signals. The combination of severe sensitization, aggressive water chemistry, dynamic straining, and a small grain size tended to cause very rapid, essentially continuous cracking at numerous grain boundaries in these tests, preventing the obvious identification of discrete crack initiation events.

For laboratory tests using fracture mechanics crack growth specimens (1T CT) in LWR environments, electrochemical noise provided a less effective indication of IGSCC growth, which was monitored continuously using reversing DC potential drop. There was reasonable correlation with (lower) EPN signals and crack advance in the early stages of SCC in specimen SA-2, which was most evident during periods where the dissolved gas concentration was maintained constant. The strong response of EPN signal to changes in dissolved gas chemistry is consistent with the differences in response of the SS specimen vs. the Pt reference electrode wire.

4. Conclusion

Electrochemical potential noise (EPN) clearly shows great promise for detecting crack initiation and surface crack growth. Once the advancing crack becomes deep and moves away from the surface, the amount of electrochemical noise signal “visible” outside the crack becomes very small. This is consistent with the very limited “throwing power” of low conductivity solutions like pure water, and with the highly restricted geometry of a tight, high aspect ratio crack. The EPN signal clearly increases with the number of active grain boundaries and with probes that are placed in close proximity to the surface.

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