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Time-dependent leak behavior of flawed Alloy 600 tube specimens at constant pressure☆

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ABSTRACT

Leak rate testing has been performed using Alloy 600 tube specimens with throughwall flaws. Some specimens have shown time-dependent leak behavior at constant pressure conditions. Fractographic characterization was performed to identify the time-dependent crack growth mechanism. The fracture surface of the specimens showed the typical features of ductile fracture, as well as the distinct crystallographic facets, typical of fatigue crack growth at low ΔK level. Structural vibration appears to have been caused by the oscillation of pressure, induced by a high-pressure pump used in a test facility, and by the water jet/tube structure interaction. Analyses of the leak behaviors and crack growth indicated that both the high-pressure pump and the water jet could significantly contribute to fatigue crack growth. To determine whether the fatigue crack growth during the leak testing can occur solely by the water jet effect, leak rate tests at constant pressure without the high-pressure pump need to be performed.

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1. Introduction

Argonne National Laboratory (ANL) has performed several series of leak rate tests on steam generator (SG) tubing containing laboratory-grown stress corrosion cracking (SCC), under sponsorship of the U.S. Nuclear Regulatory Commission (NRC). The test results have previously been published [1,2]. In some cases, dramatic increases in leak rates have been observed over relatively short time periods under nominally constant pressure conditions (nominally 17.3 MPa (2500 psig)). Fig. 1 shows an example of time-dependent leak rates observed for laboratory-grown SCC specimen SGL-900 during room temperature testing.

A series of tests were also conducted on specimens with trapezoidal electric discharge machining (EDM) notches (outside diameter [OD] length shorter than inside diameter [ID] length), which also showed the time-dependent behavior [3]. Post-test visual examination clearly revealed that the OD crack length of these EDM-notched specimens had increased by tearing of the tapered ligaments ahead of the notch tips. Specimens with rectangular throughwall (TW) EDM notches (10–15 mm [0.4–0.6 in.] length) also showed a time-dependent increase in leak rate under constant pressure (9.1–12 MPa [1300-1700 psig]) hold and post-test visual examination showed clear evidence of notch tip tearing through full-thickness material [3].

Hwang et al. reported a time-dependent increase in leak rates of Alloy 600 tubing at constant pressure [4,5]. They used a similar test system as used for the ANL leak rate tests, but their leak rates were relatively low and they did not keep the pressure constant for more than 1 h.

At one nuclear power plant, a SG tube was tested in-situ to obtain the burst pressure and leakage potential for a crack-like indication [3]. The results from this test are not directly comparable to those observed in the ANL leak rate tests because the test pressure was higher (approx. 28 MPa [4000 psig]) and the hold time at constant pressures was much shorter than those in the ANL tests. However, the results showed that the leak rate increased for 1–2 min during the initial test period at constant pressure.

Such time-dependent leak rate increases suggest that the time-dependent crack growth can occur at room temperature in Alloy 600 SG tube specimens tested in relatively non-corrosive water (tap water). The mechanism of the time-dependent leak rate and crack growth at constant pressure is not clearly understood yet. Since tap

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