Development of an in-situ measurement technique for a PWSCC crack length determination

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1. Introduction

Primary water stress corrosion cracking (PWSCC) in reactor pressure vessel head penetration nozzles, their welded parts, and steam generator tubes at pressurized water reactors have been found in many countries [1]. Their failure mechanisms have not been fully understood up to now, however, a precise and non-destructive measurement of a crack length during PWSCC is recognized as a key parameter to properly assess the reliability/integrity of nuclear core components in primary water environments. To achieve this goal, an in-situ measurement technique was developed using the DCPD (direct current potential drop) method. In the present study, this system is described, and some results of the test are given.

2. Results and Discussion

2.1 DCPD voltage measurement

In the experiment, a 1/2 CT (compact tension) specimen was used, and the schematic configuration of the DCPD system is shown in Fig. 1. Direct current of 5 A is applied to the CT specimen, and the current is periodically reversed via programmed current source. At the same time, the voltage drops are measured from the CT specimen and a reference coupon through digital voltmeters (DVMs), and then the crack length is calculated by the Hicks and Pichard (H&P) equation on the basis of the measured voltages [2,3]. The reference coupon prepared with the same material as the CT specimen is equipped to calibrate the material's resistivity change occurred after the long term operation at high temperature.

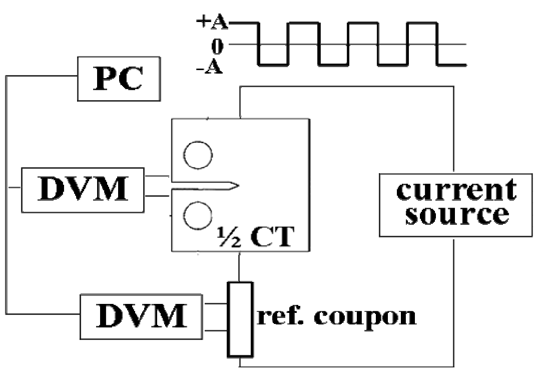

Fig. 1. Schematic configuration of the DCPD system.

2.2 Results from the fatigue cracking

It is essential to examine the validity of crack length conversion from the voltage measurement. To do this, the CT specimens were fatigue cracked in the air, and then the fractured surfaces were observed by optical microscopy. The fracture morphology of a specimen after a fatigue cracking is shown in Fig. 2. In the figure, the dark area just below the notch tip shows the fatigue cracked region, and the average crack length was measured as 2.01 mm.

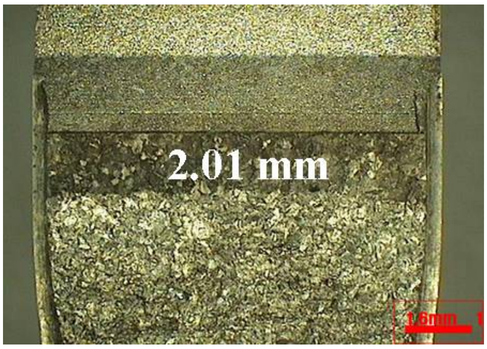

Fig. 2 Optical micrograph showing the fracture morphology of a CT specimen after fatigue cracking.

The crack length calculated from the modified H&P equation with measured voltages as input data is given in Fig. 3. In the figure, the voltage ratio represents the ratio of the present value (V_a) to the initial value (V_r) as a reference voltage. At the final stage of the fatigue test, the crack length was calculated as 2.06 mm, which agreed well with that of the real value of 2.01 mm.

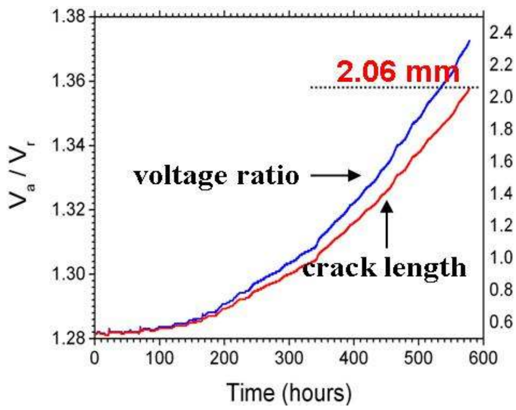

Fig. 3. Voltage ratio and calculated crack length from the measured voltages and modified H&P equation.

2.3 Sep up for PWSCC test

The PWSCC test is now in progress under the simulated primary water conditions, that is, 1200 ppm B + 2 ppm Li containing pure water at 340 ℃, dissolved oxygen contents below 5 ppb, hydrogen partial pressure of 14.3 psi, and an internal pressure of 2300 psi. The stress intensity factor at a crack tip was maintained at 30 MPa√ m. The upper head of an autoclave, a part of the PWSCC loop system, is shown in Fig. 4. In the figure, current and voltage lead wires were prepared with Pt, and Ag/AgCl was used as a reference electrode to measure the electrochemical potential (ECP) of the specimen. All the lead wires inside the autoclave were electrically insulated with alumina tubes. Major test parameters such as temperature, load, displacement, pH, conductivity, ECP and D.O. were being monitored and collected by PC through an A/D converter.

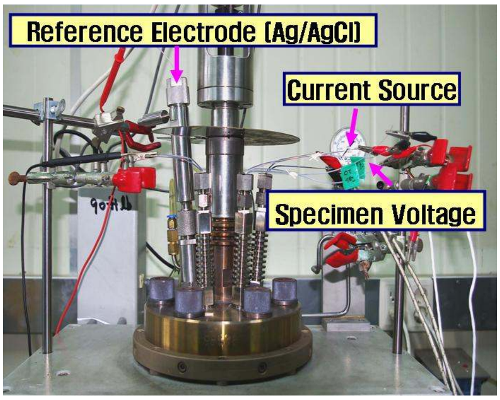

Fig. 4. Photo showing the upper head of an autoclave.

3. Conclusions

An in-situ measurement technique for a PWSCC crack length determination was developed, and it was found that the estimated crack length from the DCPD voltage measurement agreed well with the real value obtained from the fractured surface after a test. PWSCC test with CT specimens are now in progress an with acquisition of the major experimental parameters.

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