Development of Eddy Current Monitoring System and Its Application to Crack Propagation Monitoring

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This paper describes the feasibility of Eddy Current Monitoring (ECM) system as an in-situ evaluation method of crack propagation in a Boiling Water Reactor (BWR) environment. For the purpose, we explain an ECM experiment conducted at a System Safety Benchmark Facility (SSBF) with a large-scale austenitic stainless steel pipe specimen. Several slits were prepared at the Heat Affected Zones (HAZs) and weld lines from the inner surface. After exerting the load, Eddy Current Testing (ECT) probes attached on the outer surface of the specimen provide the crack propagation signals. Numerical simulation of eddy current signals based on the experimental conditions indicates that this system is capable of monitoring the crack growth in BWR environments.

Keywords: Eddy Current Monitoring, Crack Propagation, Boiling Water Reactor, Numerical Simulation

1. Introduction

In recent years, more economical and efficient condition-based maintenance methods have been required, and eddy current technique has been applied in some studies [1]. Especially, they are required in nuclear industries. Based on this viewpoint, we explain the in-situ Eddy Current Monitoring (ECM) system [2] and discuss its feasibility in a Boiling Water Reactor (BWR) environment.

2. Experiment

The ECM experiment in this study was conducted at a System Safety Benchmark Facility (SSBF) located in Fracture and Reliability Research Institute of Tohoku University. The SSBF was designed and constructed to assess safety and reliability of welded pipes under BWR conditions. The large-scale pipe specimens made of stainless steels 304, 304L, and 316L, jointed by weld joints of nickel based alloy 182 were installed in SSBF. Several semi-elliptical slits were prepared at the HAZs and weld lines from the inner surface of the pipe specimens. High temperature water of 288℃ flows into the pipe specimen at the pressure of 9MPa. A cyclic tensile load from both edges of the pipe was applied for propagating crack.

Figure 1 shows the ECM system installed in the SSBF. The ECM system consists of the ECT probes and instrument. Each probe has a pair of sensors with two exciting coils and a pair of differential pick-up coil. This sensor structure assures high sensitivity of cracks in thick-walled materials [3].

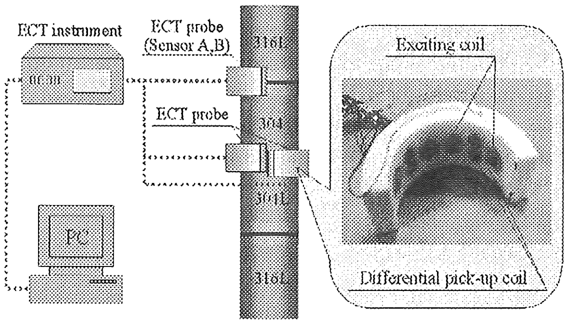

Fig.1 Schematic drawing of ECM system.

3. Results and Discussion

After 2293 hours from the start of experiment, the specimen showed leakage of water. Figure 2 shows the cross section at the weld line 316L-182-304. Figures 3(a) and 3(b) show the ECM signals observed by sensor A and B (in Figure 1) at the test frequency of 20kHz. It is shown that the both signals shift with phase change during the last 4days.

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Figure 3(c) shows the numerical eddy current signals based on reduced vector potential method [4]. Two computed Lissajous figures are shown in Figure 3(c); the smaller Lissajous figure represents circumferential scanning signals on the initial crack and the larger one corresponds to propagated crack. Here, the probe scans on the outer surface of the pipe specimen. Initial eddy current signals of monitoring lie on the smaller Lissajous figure and two triangular points represent the eddy current signals to the initial cracks observed by sensors A and B. Similarly, two circular points on the larger Lissajous figure represent the eddy current signals to the propagated crack. The ECT signals of each sensor are displaced from triangular point to circular point in Figure 3(c). These displacements of ECT signals correspond to the experimental result shown in Figures 3(a) and (b). The difference in magnitude is due to the amplifier in the EC instrument. It is shown that the direction changes of two sensor voltages are opposite each other. This tendency corresponds with the experimental results. Therefore, it is confirmed that the ECM experimental signals of sensors A and B represent crack propagation.

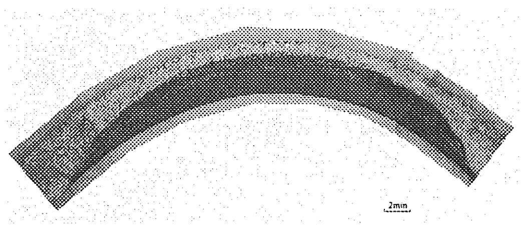

Fig.2 Cross section at the weld line.

4. Summary

In this paper, we have described a work on the in-situ ECM system. Numerical simulation shows that the system is capable of monitoring the crack growth in a BWR environment.

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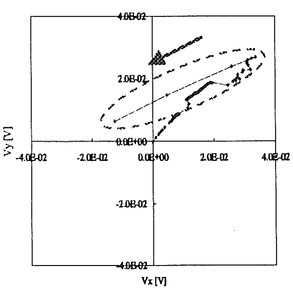
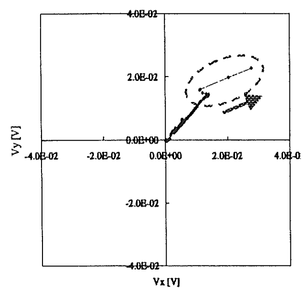
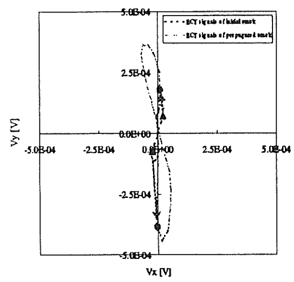


(a) Sensor A



(b) Sensor B



(c) Calculated signals

Fig.3 Comparison between experimental and calculated ECM signals of 20kHz.

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