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SSRT System Upgrade and Microhardness Measurement of Proton-Irradiation Type 316 Stainless steel

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1. Introduction

Irradiation-assisted stress corrosion cracking (IASCC) on austenitic stainless steels for boiling water reactor (BWR) environments had been reported. On the other hand, IASCC under simulated pressurized water reactor (PWR) conditions is insufficient and its mechanism is not well understood[1,2].

A study of the PWR concept includes the assessment of the effect of a neutron irradiation on a stress corrosion cracking (SCC) at a high temperature water. Neutron irradiated materials of IASCC are difficult due to their cost, shipping and handling. Techniques such as a proton irradiation are appealing alternative methods for neutron-irradiation in assessing the effects of a SCC. However, proton irradiation is required to confirm the role of in-core irradiation on a crack growth and in performing a final verification of the effect of a alternative irradiation on candidate alloys[3].

This paper aims to introduce the recently developed SCC test facility for IASCC on proton-irradiated specimens. Micro hardness evaluation on the proton irradiated type 316 SS was also described.

2. Experimental

2.1. Test materials

Type 316 stainless steel was used in the solution-annealed condition without any additional processing or preparation other than a surface polishing and cleaning. After the tensile specimens were made, the surfaces were ground using SiC paper to a final finish of #2000 grit. The samples that were made by Jet-thinning from the irradiated side for 7-10 seconds in a 10% perchloric acid + 90% methanol at ~ -50℃ at 50V. The specimens were irradiated at 1, 3, 5 displacements per atom(dpa) by using Michigan Ion Beam Facility at University of Michigan.

2.2. Nickel Electroplating for Hardness test

Irradiation specimens for TEM are not good for a hardness test on the account of their thin thickness. The proton irradiated surfaces were electroplated with Ni as follows. First, the irradiated specimen acting as an electrode and nickel plates as the opposite electrode were positioned in the activation solution for 1 minute, and then an opposite current of 20mA/cm^2 was applied on the specimen for 30 seconds. Then the polarity of the electrodes was exchanged and kept in the solution for 5 minutes. Secondly, the electrodes were put out of the activation solution and put into the electroplating solution. While the applied current was increased to 90mA/cm^2, the solution was stirred by using low nitrogen gas. It took 48 hours to get a layer of Ni deposition of 2mm.

This specimen was measured with a load of 10g applied for 10 second retention time of Micro-Vickers hardness. The hardness test was conducted on cross-sections of plate specimen.

2.3 Construction of Water Loop System

The test facility consists of a closed-loop, flowing water system as shown in Fig.1. The water chemistry was controlled using a water board, where distilled water was stored in two glass columns. Gas was bubbled through the columns and a small positive gas pressure can be applied in order to control the dissolved gas content of the water. Both columns are connected to a recirculation loop that directs the water through an ion exchanger to maintain purity. As the primary column contains the water to be used for the experiment, a conductivity meter and hydrogen meter and an oxygen meter are installed in the recirculation loop to permit continuous monitoring of the conductivity and dissolved oxygen content of the water at room temperature and atmospheric pressure. When the desired conditions are reached, the water is pressurized and heated up to a temperature close to the target temperature before it flows into the autoclave. A high-pressure liquid chromatographic pump pushes the water from the primary column to the autoclave through the pre-heater and controls the flow rate for the experiment up to 150- 200 ml/min. The water finally goes through a 60 ㎛ filter and a back pressure regulator (BPR), where the pressure is reduced. The section of the loop between the pump and the BPR is at the system pressure, controlled by the BPR, and measured by a pressure gage and two pressure transducers After the BPR, the water is at atmospheric pressure and flows through a conductivity meter and hydrogen meter and an oxygen meter before returning to the primary column.

2.4. SCC test system (SSRT)

The SCC facility provides the capability to perform stress corrosion cracking experiments in pure water, up to 2500 Psi of pressure and 340℃, in a controlled, refreshed environment. The SSRT consisted of an autoclave head with MST (Multi Specimens Tensile test) and CT(Compact Tension) Specimen. The make-up and control on the environment was performed in the water loop. Constant strain rate, constant load and constant *K* experiments can be conducted, in addition to fatigue pre-cracking and programmed loading sequences.

3. Discussion and Results

The hardness test results are shown in Fig. 2. Increase of the hardness was observed at a depth of 25 ㎛ from the surface. Unirradiated area showed a tendency of a decrease in the hardness.

A facility for a stress corrosion cracking test on proton-irradiated specimens in a high temperature water has been built at KAERI.

Experiments can be conducted in pure water, up to 2500Psi of a pressure and 340℃, in a controlled, refreshed environment. In this environment, four tensile specimens will be loaded under a constant extension rate.

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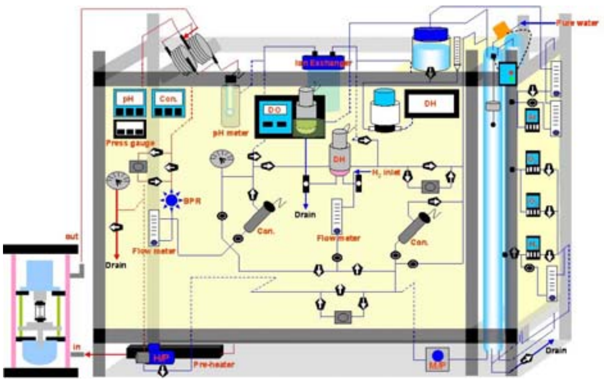

Fig.1. Water loop system of KAERI

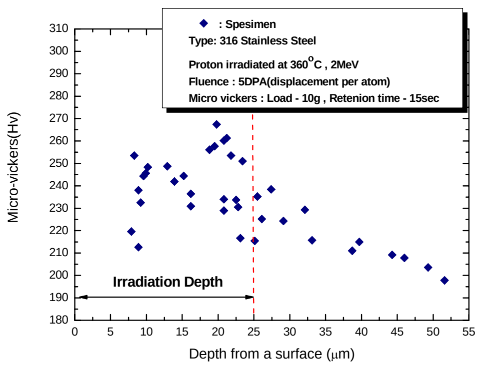

Fig.2. Hardness test of Proton-Irradiation Specimen