A review on specimen and water loop design for IASCC of proton-irradiated stainless steels

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1. Introduction

Irradiation assisted stress corrosion cracking (IASCC) has been a problem in the nuclear industry for the last 30 years. [1−3] Although many papers have been published on the deformation microstructure of neutron irradiated stainless steels, very few deal with proton-irradiated samples. A fair comparison of the deformation microstructures between these two types of irradiations is not available. However, the overall microchemistry, microstructure, hardening and SCC behavior of proton- and neutron-irradiated 304SS and 316SS samples were found to be in excellent agreement. [2] The deformation mode and deformation microstructures are similar in both proton- and neutron-irradiated stainless steels.

The high cost of fabricating, irradiating, shipping, handling, and testing neutron-irradiated materials makes it attractive to perform experiments using an alternative irradiation technique such as proton irradiation. This technique was used to evaluate the effect of specific solute additions on an IASCC susceptibility of stainless steels.

In this work, we tried to prepare proton irradiation specimens with neutron irradiation specimens. And a water loop system in order to conduct a stress corrosion cracking of the proton-irradiated specimens has been fabricated. Four tensile specimens can be loaded under a constant extension rate. The loop system permits to load 1/2 CT under constant K and to measure the crack propagation rate by using a direct current potential drop technique.

2. Experimental

2.1 Alloy selection and sample preparation

Alloys were used in the solution-annealed condition without any additional processing or preparation other than surface polishing and cleaning. After the tensile specimens and 1/2 CT specimens (dimensions are shown in Fig. 1.) were made, the surfaces were ground using SiC paper to a final finish of #4000 grit. The samples were then electropolished in a 60% phosphoric, 40% sulfuric acid solution at room temperature to get a mirror like surfaces prior to irradiation experiment.

2.2. Proton irradiations and constant extension rate tensile (CERT) tests

Proton irradiation of samples was performed using a specially designed stage connected to the General Ionex Tandetron accelerator at the Michigan Ion Beam Laboratory. [4] Irradiations were conducted using 3.2 MeV protons at a dose rate of approximately 8.5×10^{-6} dpa/s, resulting in a nearly uniform damage rate through the first 35 μm of the proton range (total = ~ 40 μm). Irradiations were conducted to 1.0 and 5.5 dpa, where dpa is calculated using the stopping and range of ions in matter (SRIM2003) with a displacement energy of 40 eV. The sample temperature was maintained at 360 ± 10 ^oC for the duration of the irradiation. The CERT tests were conducted in a multiple specimen test system. The CERT setup consists of an autoclave, a load frame, and a computer driven 30 kN load train for straining of the samples. Four independent tensile load cells measured the tensile force on each sample. After the tensile specimens were loaded, the autoclave was sealed and purged with flowing Ar to ensure that all the air was removed from the autoclave. The system was then heated to 288 ^oC. After the temperature was stabilized, the load was applied and the specimens were pulled with a strain rate of 3.5×10^{-7}/s.

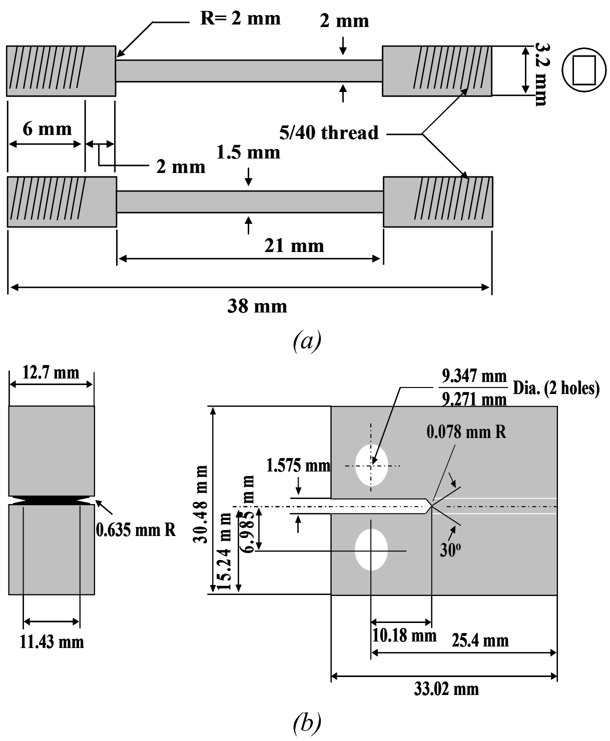

Fig. 1. Dimensions of the tested (a) tensile specimens and (b) 1/2 CT specimens.

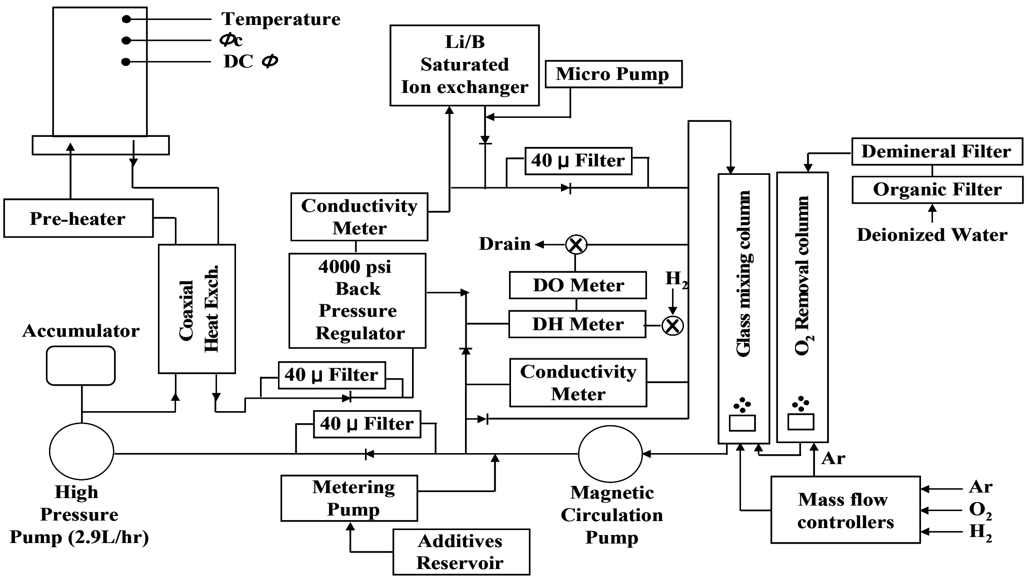

Fig. 2. Design of loop system

2.3. Water Loop System

The testing loop system consists of a closed-loop, flowing water system. The water chemistry is first prepared and controlled using a water board, where distilled water is stored in two glass columns. Gas is bubbled through the columns and a small positive gas pressure can be applied in order to control the dissolved oxygen content of the water. Both columns are connected to a recirculation loop that directs the water through an ion exchanger to maintain a purity. As the primary column contains the water to be used for the experiment, a conductivity, an oxygen and a hydrogen meter are installed in the recirculation loop to permit continuous monitoring of the conductivity, dissolved oxygen and hydrogen 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. This is achieved by flowing the water through a regenerative heat exchanger that takes its heat from the water leaving the autoclave. The water then flows through a coil heated. After flowing through the autoclave the water is cooled down to room temperature before it returns to the water board. The water finally goes through a 40 μm 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 (located both at the inlet line and the outlet line).

After the BPR, the water is at atmospheric pressure and flows through a conductivity, an oxygen and a hydrogen meter before returning to the primary column. All water system parameters such as temperature, pressure, dissolved oxygen and hydrogen content, conductivity are continuously monitored and recorded.

3. Conclusion

KAERI has established a stress corrosion crack test facility for proton irradiation specimens. A sample preparation procedure and a design of water loop for the test are set up.

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