Effect of dissolved hydrogen concentration on IASCC initiation susceptibility of type 316 stainless steels

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1. Introduction

Dissolved hydrogen(DH) concentration in the PWR primary water has been controlled at 25 ~ 35 cc/kg·H_2O, this condition has been optimized to mitigate primary water stress corrosion cracking(PWSCC) of nickel-based alloys considering various experimental results. The effect of DH concentration on PWSCC of nickel-based alloys has been studied, higher dissolved hydrogen strategy is being considered to obtain partial mitigation of PWSCC. In the case of stainless steels, it is necessary to research the effect of DH concentration on irradiation assisted stress corrosion cracking(IASCC). In this research, we tried to evaluate the effect of DH concentration on IASCC initiation susceptibility using the proton irradiated type 316 stainless steels under the condition of simulated primary water.

2. Methods and Results

2.1 Materials and Specimens

The test material is type 316L stainless steel, the compositions of the alloy are as follow table 1.

Table 1. Chemical compositions of the test materials

C	Cr	Ni	P	Mo
0.047	16.7	10.8	0.1	2.0
Mn	Si	S	Fe	(Unit:wt%)
1.3	0.59	0.001	Bal.	

The test specimens were produced for slow strain rate test(SSRT) with a gage length of 23 mm by electric discharge machining (EDM).

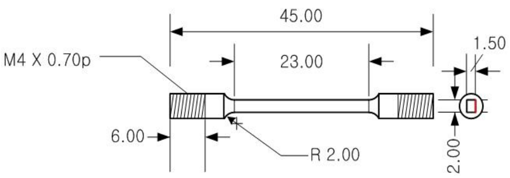

Fig. 1. SSRT test specimen

2.2 Proton Irradiations

Proton irradiations were performed using the General Ionex Tandetron accelerator at the Michigan Ion Beam Laboratory(MIBL) in the University of Michigan. Irradiation were conducted using 2.0 MeV protons at 40 uA of current to 1, 3, 5 and 10 dpa by controlling irradiation time. Fluence and dose rate were calculated from the irradiation conditions by using SRIM code.

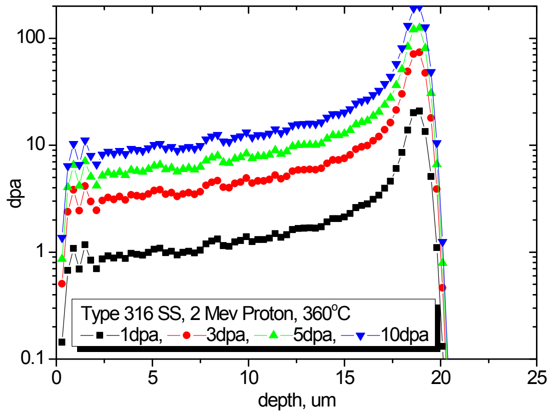

Fig. 2. Irradiation doses calculated by SRIM code

2.3 SSRT

Slow strain rate tests (SSRT) were performed in the autoclave with the simulated primary water loop. The condition of water chemistry was 1200 ppm of B, 2 ppm of Li, 6 ~ 6.5 of pH, 21.2 ~ 21.5 of conductivity and under 5 ppb of dissolved oxygen. The temperature and pressure of autoclave were 340 °C and 2400 psi. The strain rate was 3.4×10^{-7}/s and the tests were conducted to 10 % of strain. 25 and 50 cc/kg·H_2O of DH were applied to evaluate the effect of DH concentration on SCC initiation.

Fig. 3. Primary water loop and autoclave

2.4 The crack length per unit area

The irradiation surfaces of the specimens after the SSRTs were observed (Fig. 4). We could find the irradiation area by the color difference. The high resolution (x1000) images on the irradiation surfaces were obtained using 3D digital microscope (Fig. 5). All observed intergranular(IG) cracks were counted and their length was measured. The crack length per unit area was calculated by dividing the summation of length of all cracks by the measured area of 3.7024 mm^2.

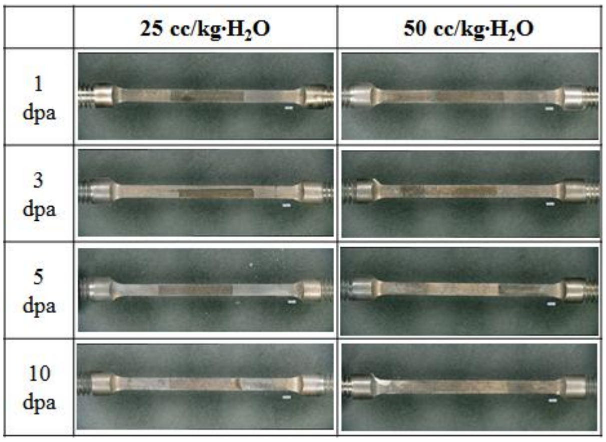

Fig. 4. The specimens after SSRTs

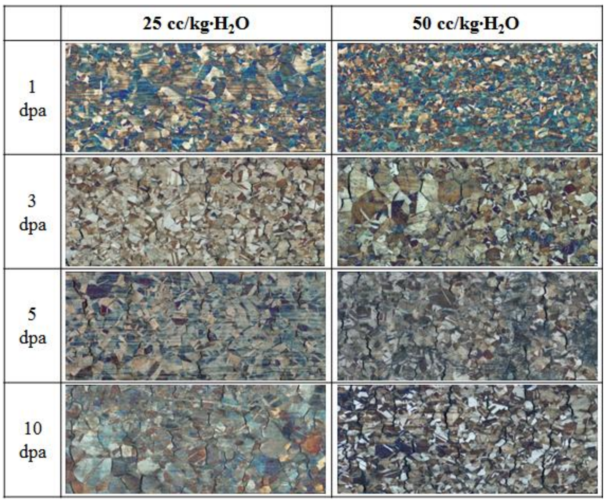

Fig. 5. The high resolution images on the irradiation surfaces

2.5 IASCC initiation susceptibility

The calculated crack length per unit area was shown as Fig 6. In the graph, the result of 3 specimen at the 25 cc/kg·H_2O DH condition was indicated error data because of the irradiation condition of the sample. Removing the error data and using the log scale, the graph was re-plotted (Fig. 7).

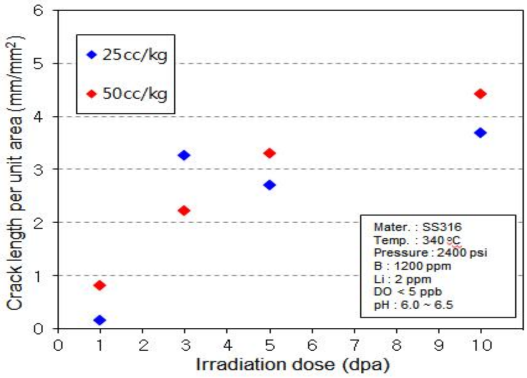

Fig. 6. Crack length per unit area

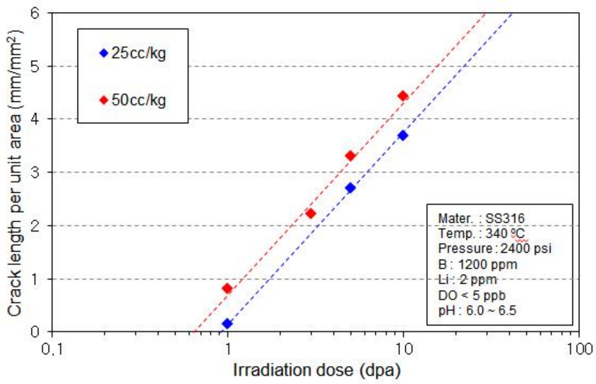

Fig. 7. Crack length per unit area (log scale)

IASCC initiation susceptibility was increased by increasing irradiation dose, crack length per unit area and irradiation dose showed a linear relation at log scale. DH concentration affected the IASCC initiation susceptibility, which was increased by increasing DH concentration.

3. Conclusions

The slow strain rate tests were performed using the proton irradiated type 316 stainless steels at the simulated primary water conditions, crack length per unit area for all tested specimens were calculated. IASCC initiation susceptibility was increased by increasing irradiation doses and by increasing DH concentration. We need to consider the effect of DH change on the degradation of reactor internal materials when the higher DH concentration strategy is discussed.

ACKNOWLEDGEMENT

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Science, ICT & Future Planning(2012M2A8A4025880).