A study on the optimum electropolishing conditions for austenitic stainless steel through electrochemical experiments

Eun Byeoul Jo[1,2] Seok Su Sohn[2] and Min-Jae Choi[1,†]
[1]*Materials Safety Technology Development Division, Korea Atomic Energy Research Institute, 989-111 Daedeok-dearo, Yuseong-gu, Daejeon, Korea*
[2]*Department of Materials Science and Engineering, Korea University, 145 Anam-ro, Seongbuk-gu, Seoul, Korea*
[†]*Corresponding author: mjchoi@kaeri.re.kr*

1. Introduction

Slow strain rate testing (SSRT) has been mainly used to study the initiation characteristics of irradiation-assisted stress correction cracking (IASCC) of austenitic stainless steels. When using proton irradiated specimens, the precise observation of micro-cracks on the sample surface is very important for quantification of IASCC initiation susceptibility, so the specimen should have a very fine surface roughness. Surface roughness of the samples must be controlled at a level of several tens of nm before proton irradiation, electropolishing was performed after sandpaper polishing. In this study, we tried to find the optimum electropolishing condition of austenitic stainless steel. The equipment of electrochemical experiments was designed to be suitable for the SSRT specimens, the polarization experiments were performed to find the optimum current density condition. Electropolishing experiments were performed under various conditions, and the optimum electropolishing conditions were established through surface roughness measurement.

2. Experimental

2.1. Specimen

Type 316 austenitic stainless steel was used as the specimen. The shape and design of the specimen are shown in Figure. 1. Samples were polished using SiC sandpapers from #800 to #4000, and polished with 1 um alumina suspension.

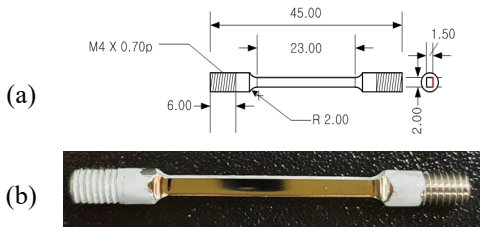

Fig. 1. SSRT specimen (a) drawing and (b) image

2.2. Polarization experiments

In order to estimate the current density to the electropolishing, a polarization test was performed. In the polarization experiment, mixed solution of sulfuric acid, phosphoric acid, and glycerol (1:2:1) were used as electrolytes, and a three-electrode system was constructed using a reference electrode (SCE), a working electrode, and a counter electrode (Pt). The working electrode was made of a jig in consideration of the shape of the SSRT specimen.

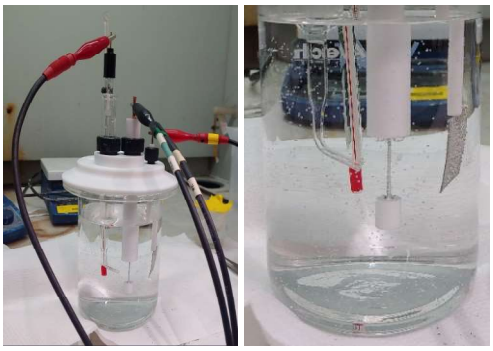

Fig. 2. Corrosion cell kit for polarization experiment using SSRT specimen

2.3. Electropolishing experiments

For electropolishing experiments, a jig was manufactured in consideration of the shape of the SSRT specimen. The specimen holder was used as an anode to fix the specimen and electropolish the specimen surface. Digital multimeter (Keithly 2651A) was used to convert and apply voltage, current, and resistance to DC voltage. The electrolyte was composed of sulfuric acid, phosphoric acid, and glycerol (1:2:1).

Fig. 3. Experimental equipment for electropolishing

3. Results

In order to obtain the optimal current density for electropolishing, polarization experiments were performed under various temperature and time conditions. As a result of polarization experiments under the experimental conditions of 40 to 80 ℃ and 1 to 5 minutes, it was confirmed that 60 ℃ and 3 minute were appropriate condition. Figure 4 is a graph showing the polarization curve according to the stirring speed. From the experimental results, it was found that a stirring speed must be 200 RPM or more in order to form an appropriate plateau section in the polarization curves.

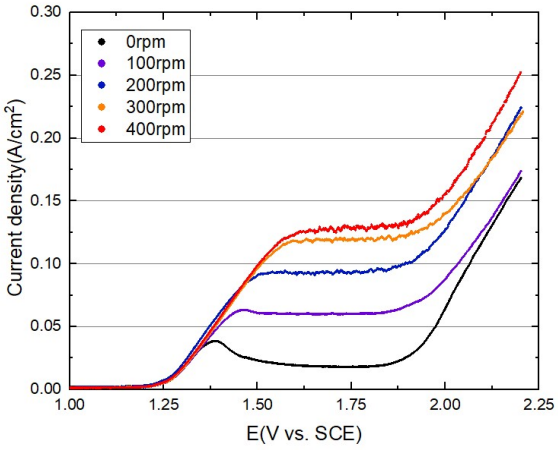

Fig. 4. Current density-Voltage curves with different stirring speed

Experiments were performed at current densities of 0.05, 0.15, 0.5, 1, and 2A under conditions of electropolishing temperature of 60°C, time of 3 minutes and stirring speed of 200 RPM. And then, surface roughness after electropolishing were observed by the 3D surface profile (Nanosystem, NV-F3200). It was found that etched surface was observed at 0.05A, it means this current density was too low to polish the surface. At 0.15A, the Ra had the lowest value and excellent quality of electropolishing was also observed. As the current increases, the surface roughness increases and several fittings were observed.

Figure 5 shows the surface roughness measurement results according to the electropolishing temperature of 60°C, the time of 3 minutes, current density of 0.15 A, and stirring speeds of 0, 200 RPM. From the Ra value, it confirmed that surface roughness of 30 nm or less can be obtained when electropolishing is performed under optimal conditions regardless of stirring the electrolyte. However, Rmax value was decreased by stirring dramatically, it means that stirring is essential for electropolishing of uniform quality.

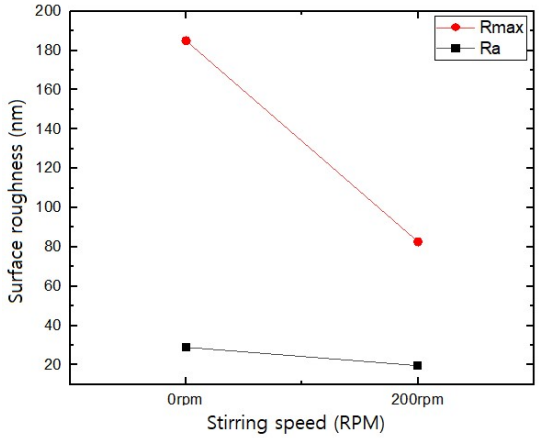

Fig. 5. The surface roughness measurement results

4. Conclusion

The optimum electropolishing experimental conditions were established through the polarization test and the measurement of surface roughness after electropolishing. The optimum condition was the electropolishing temperature of 60°C, the time of 3 minutes, current density of 0.15 A, and stirring speeds of 200 RPM or more. As a result of 3D surface profiling, surface roughness was measured to be 20 nm or less under optimal conditions, which was sufficient for IASCC experiments.

REFERENCES

[1] J. W. Park, E. S. Lee, and J.B. Song, A Study on the Machining Characteristics of Electropolishing for Stainless Steel, Korean Society of Machine Tool Engineers, 8, 186 (1998)