Effect of an Inhibitor on A Stress Corrosion Cracking of Alloy 600 by Using SSRT

Mi-Ae Kim, Dong-Jin Kim, Joung Soo Kim, Hong Pyo Kim
Division of Nuclear Material Technology Developments, Korea Atomic Energy Research Institute(KAERI), Yuseong, Daejeon, Korea, 305-600

1. Introduction

Steam generator tubes in pressurized water reactors (PWRs) form a pressure boundary between the primary and secondary sides. Austenitic stainless steel was used initially for the tubing, but it was changed to Alloy 600 as the result of corrosion problems. A lot of problems related to a corrosion have been reported in the Alloy 600 steam generator tubes of operating nuclear power plants (NPP), an outer diameter stress corrosion cracking (ODSCC) and an intergranular attack (IGA) which have been occurring in Alloy 600 tubes are known to be the leading causes of a PWR steam generator tube plugging in the USA and worldwide [1].

Numerous studies for mitigating or avoiding these corrosion related problems in the steam generators have been carried out [2]. One approach that has shown significant promise in laboratory tests is the use of chemical inhibitors [3]. Adding chemical inhibitors to the secondary side of the steam generators as a method that can be applied to currently operating plants has been extensively studied [4-6].

In this work, SSRT tests were performed to examine the role of an inhibitor for Alloy 600 in neutral solutions and acidic solutions. SSRT tests were performed with Alloy 600 samples at OCP in solutions with and without NiB as an inhibitor.

2. Experimental

The materials used in this study were Alloy 600, and their chemical compositions are given in Table 1. Alloy 600 is a high temperature mill annealed (HTMA) alloy at 1024°C for 3minutes.

Slow strain rate tensile (SSRT) tests were performed in solutions at 315°C and at an open circuit potential. The strain rate of the SSRT tests was $2 \times 10^{-7}s^{-1}$. The designs of the SSRT test specimens are shown in Figure 1. All the SSRT test solutions were deaerated by a purging with a high purity nitrogen gas to remove the dissolved oxygen in the solutions for 24 hours before the tests started.

Surfaces in the gauge section and the fracture surfaces after the SSRT tests were examined with SEM.

3. Results and discussion

Slow strain rate tensile (SSRT) tests of Alloy 600 tube specimens were carried out at OCP in neutral solutions and acidic solutions containing 10,000ppm PbO with and without NiB at 315℃. The results are summarized in Table 2.

The area of a SCC on the fracture surfaces was calculated using an image analyzer. The fraction of SCC of Alloy 600 was significantly decreased by the addition of NiB to the neutral solutions and acidic solutions containing PbO. It is shown that the solutions without NiB are more susceptible to a SCC than the solutions with NiB.

Fig. 2 and Fig. 3 show the stress-strain curves of the Alloy 600 determined in solutions with and without NiB. The ultimate tensile strength (UTS) of Alloy 600 decreased more in the 0.01M Na_2SO_4, 0.01M $NaHSO_4$ + 0.01M Na_2SO_4 solutions containing 10,000ppm PbO without NiB than with NiB. The elongation of the Alloy 600 tested in the 0.01M Na_2SO_4, 0.01M $NaHSO_4$ + 0.01M Na_2SO_4 solutions containing 10,000ppm PbO was about 26% and 40%, respectively, whereas those in the 0.01M Na_2SO_4, 0.01M $NaHSO_4$ + 0.01M Na_2SO_4 solutions containing 10,000ppm PbO with NiB was about 38% and 52%, respectively. The leaded solutions without NiB noticeably deteriorated the tensile properties of Alloy 600.

From these results, it can be concluded that NiB could significantly enhance the corrosion resistance of Alloy 600 in neutral solutions and acidic solutions. However, the role of NiB is not clear regarding whether it modifies the oxide structure or competes with PbO for a site at a crack tip.

4. Conclusion

Alloy 600 suffered a severe SCC for the 315℃ PbO aqueous solutions under the SSRT loading condition. Based on the results of the SSRT tests the following conclusions are drawn:

Addition of NiB plays an important role in the development of a cracking due to a corrosion. The leaded solutions without NiB deteriorated the tensile properties of Alloy 600. The absence of a SCC on the fractured surface of Alloy 600 tested in the neutral solution and acidic solution containing NiB is attributed to a reduced corrosion rate.

This study revealled a possibility that NiB may be applied to nuclear power plants.

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Table 1 Chemical compositions of Alloy 600 (wt %)

Material	C	Si	Mn	P	Cr	Ni	Fe
Alloy600	0.025	0.05	0.22	0.07	15.67	75.21	8.24
Material	Co	Ti	Cu	Al	B	S	N
Alloy600	0.005	0.39	0.011	0.15	0.0014	0.001	0.0103

Table 2 SCC of Alloy 600 HTMA at OCP in solutions of 315℃

Material	*Solution*	*Test duration (hr)*	*Fraction of SCC(%)*	*El (%)*
Alloy 600 HTMA	0.01M Na_2SO_4+10,000ppm PbO	282	85.0	26.0
	0.01M Na_2SO_4+10,000ppm PbO+4g/l NiB	432	75.0	38.0
	0.01M $NaHSO_4$+0.01M Na_2SO_4+10,000ppm PbO	498	75.4	40.2
	0.01M $NaHSO_4$+0.01M Na_2SO_4+10,000ppm PbO+4g/l NiB	725	66.0	52.4

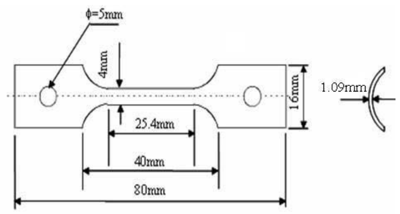

Figure 1. Shapes and dimensions of the slow strain rate tensile specimen

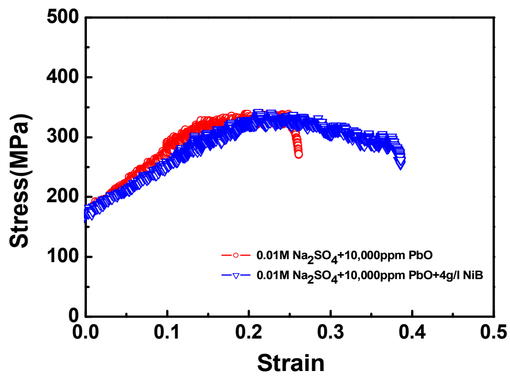

Figure 2. Stress-strain curves of Alloy 600 HTMA in Na_2SO_4 solutions with/without NiB at 315℃

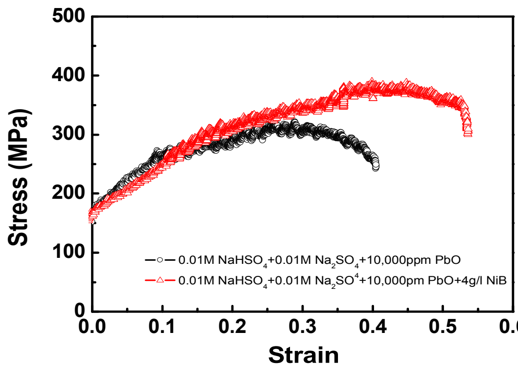

Figure 3. Stress-strain curves of Alloy 600 HTMA in $NaHSO_4$+Na_2SO_4 solutions with/without NiB at 315℃