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Effect of Additives on a Stress Corrosion Cracking of Alloy 600 in a PbO-added neutral solution

Mi-Ae Kim*, Dong Jin Kim, Joung Soo Kim, Hong Pyo Kim
Nuclear Materials Research Division, Korea Atomic Energy Research Institute(KAERI), Yuseong-gu, Daejeon, 305-353
**Corresponding author: makim@kaeri.re.kr*

1. Introduction

Steam generator tubes in pressurized water reactors (PWRs) form a pressure boundary between the primary and secondary sides. 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].

Pb is known to be a cause of the SCC of the SG tubes in some power plants. It would be best to prevent ingress of Pb into the SGs. If that is not possible, the second possible option would be understanding the Pb-induced SCC(PbSCC) behavior and finding some inhibitive additives for suppressing the PbSCC.

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 study, SSRT tests were performed to examine the role of additives for Alloy 600 in PbO-added neutral solution.

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 neutral solutions containing PbO at 315°C. The SSRT tests were carried out using a Ni autoclave of 0.5 gallon at 315°C and an open circuit potential.

Figure 1. shows the shape and dimensions of the SSRT test samples used in this study. The strain rate of the SSRT tests was $2 \times 10^{-7} s^{-1}$. 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

In order to evaluate the performance of the additives, slow strain rate tensile (SSRT) tests of Alloy 600 tube specimens were carried out at OCP in neutral solutions containing 10,000ppm PbO with additives at 315℃. The results are summarized in figure 2.

As shown in figure 2, elongations of the specimens tested in this condition increased from 38.0% to 54.2% with the added NiB(4g/l) and TiO_2(4g/l). The elongation of Alloy 600 decreased leaded solution with the added H_3BO_3(10g/l).

From these results, it can be concluded that NiB and TiO_2 could significantly enhance the corrosion resistance of Alloy 600 in a leaded neutral solution. However, the role of NiB and TiO_2 is not clear regarding whether it modifies the oxide structure or competes with PbO for a site at a crack tip. The leaded neutral solution with H_3BO_3 slightly deteriorated the elongation.

The area of a SCC on the fracture surfaces was calculated using an image analyzer.

4. Conclusion

Alloy 600 suffered a severe SCC for the 315℃ neutral solutions containing PbO under the SSRT loading conditions. From the experimental observations, it can be concluded as follows;

1. NiB and TiO_2 in neutral solution containing PbO increased SCC resistance of Alloy 600.
2. The PbO-added neutral solution with H_3BO_3 accelerated the stress corrosion cracking of Alloy 600.
3. Addition of NiB and TiO_2 plays an important role in the development of a cracking due to a corrosion.

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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

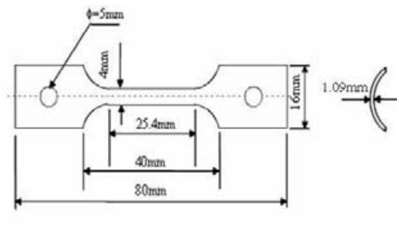

Figure 1. Shapes and dimensions of the slow strain rate tensile specimen.

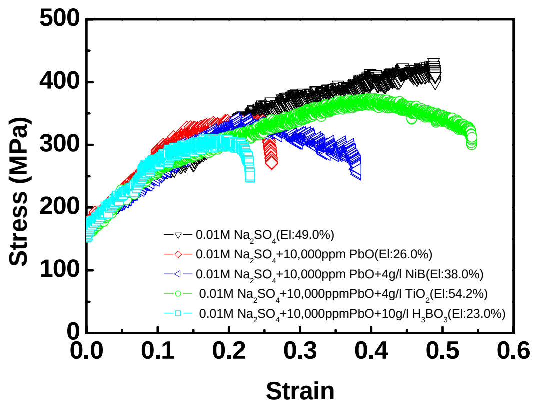

Figure 2. Stress-strain curves of Alloy 600 HTMA in Na_2SO_4 with/without PbO and additives at 315℃.