

The Influence of PbO on Stress Corrosion Cracking of Ni-Based Alloys

Byung-Hak Moon*, Dong-Jin Kim, Hong-Pyo Kim, Seong-Sik Hwang
Nuclear Materials Research Division, Korea Atomic Energy Research Institute (KAERI),
Yuseong-Gu, Daejeon, 305-353

*Corresponding author: mbh@kaeri.re.kr

1. Introduction

Ni-based alloys such as Alloy 600 and Alloy 690TT have been commonly used for steam generator tubing in pressurized water reactors (PWRs). Alloy 600 has been used for this application since the late 1960s, but this alloy is prone to stress corrosion cracking (SCC) in pure water, both acidic and alkaline solutions, and in lead-containing solutions. These persistent SCC of Alloy 600 led to the development of Alloy 690 as early as 1972. Alloy 690 is more resistant to SCC in pure water and in acidified solutions and has largely replaced Alloy 600 usually in the thermally treated form of Alloy 690TT.

It has been known that SCC of alloy 600 and alloy 690 in the secondary side of steam generators occurs mainly in a high temperature caustic solution or in S containing solutions such as $H_2S_xO_6$ and Na_2S_2O . However, lead is now being considered as a new origin of SCC of alloy 600 and alloy 690. It is known that can accumulate in the service between the tube s and sludge piled on top of the tube sheet (TTS) in steam generators. Lead compounds (PbO) have been detected in the secondary side of more than 30 nuclear power plants worldwide [1-3]. Although there have been a few reports on lead-induced SCC of these alloys including the effects of alloying elements, micro-structure and lead chemicals on SCC resistance [4-6], the mechanism of lead-induced SCC of Ni-based alloy is not yet well elucidated.

Thus, examining the influence of lead compounds (PbO) on stress corrosion cracking of alloy 600 and 690 may provide a clue why the resistance to SCC of the alloy is significantly reduced in caustic solutions contaminated with PbO.

In this study, we investigated the influence of PbO on stress corrosion cracking of Ni-based alloys.

2. Experimental

The samples used in the experiment were alloy 600HTMA and 690TT. The chemical composition of alloys is shown in Tables 1 and 2, respectively.

The slow strain rate tensile (SSRT) test is known to take a relatively shorter time and show better reproducibility compared to other test methods. The SSRT tests were carried out using a Ni autoclave of 0.5 gallons at 315°C and an open circuit potential. Tensile

specimens having a gauge length of 25.4mm were used for SSRT. The specimens were cleaned using acetone immediately before loading. The test environments for SSRT were performed in a caustic solution containing PbO at 315°C. The environment cell was designed such that the gauge length remained immersed in the test environment during the entire test duration.

In the present study, all the specimens were tested with the strain rate of $2 \times 10^{-7} s^{-1}$. The cell was filled with test solution before starting the machine. The load was applied by employing the constant extension rate mode. A pre-load of ~50lbs was applied to take care of the machine slack. The load and extension were monitored continuously by a load cell and LVDT. As there was no extension meter attached to the specimen gauge length, SSRT tests produced apparent stress-strain curves. The elongation (El) was obtained by measuring the displacement to rupture of the specimens.

The fracture surfaces were washed in distilled water and rinsed with acetone, before examination using a scanning electron microscope (SEM). From the SEM observations, the crack morphology and SCC areas were determined.

3. Results and discussion

The influence of PbO was evaluated for alloy 600HTMA and 690TT. In the case of alloy 690TT, SCC did not occur in Pb-containing 0.1M NaOH and 0.5M NaOH solution, while 16% of the surface area fractured in Pb-containing 1M NaOH. However, the fracture surface of alloy 600HTMA was fractured by SCC in Pb-containing 0.1M NaOH. These effects of PbO are represented in Fig. 1. The SCC ratio is defined on the SCC area over the cross sectional area of the specime.

Fig. 2 shows the stress-strain curves of the alloy 600HTMA and 690TT tested in Pb-containing NaOH solution. The El and ultimate tensile strength (UTS) of alloy 600HTMA tested in Pb-containing 0.1M NaOH was approximately 28% and 396MPa, respectively, whereas alloy 690TT was approximately 54% and 593MPa, respectively. There is an apparent difference in the El and UTS of the alloy 600HTMA and alloy 690TT.

Fig. 3 shows SEM images for the fracture surface of the SSRT specimen tested in a Pb-containing NaOH solution. The alloy 690TT surface in the gauge section

did not show the SCC except for few cracks, as shown in Fig. 3

4. Conclusions

From the SSRT tests and SEM images, the alloy 690TT compared to the alloy 600HTMA shows superior resistance to SCC.

REFERENCES

- [1]A. K. Agrawal, J. P. N. Paine, in: Proceedings of the 4th International Symposium on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors, Jekyll Island, Georgia, p. 7, 1990.
- [2]B. P. Miglin, J. M. Sarver, in: Proceedings of the 4th International Symposium on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors, Monterey, California, p. 757, 1992.
- [3]A. Rocher, F. Cattant, D. Buisine, B. Prioux, M. Helie, in: Proceedings of the Contribution of Materials Investigation to the Resolution of Problems Encountered in PWRs, Fontevraud III, p. 537, 1994.
- [4]J. M. Sarver, in: Proceedings of the 1987 EPRI Workshop on Secondary-side Intergranular Corrosion Mechanisms, Vol. 2, p. C11, 1988.
- [5]F. Vaccaro, in: Proceedings of the 1987 EPRI Workshop on Secondary-side Intergranular Corrosion Mechanisms, Vol. 2, p. C11, 1988.
- [6]T. Sakai, T. Senjuh, K. Aoki, T. Shigemitsu, Y. Kiah, in: Proceedings of the 4th International Symposium on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors, Monterey, California, p. 764, 1992.

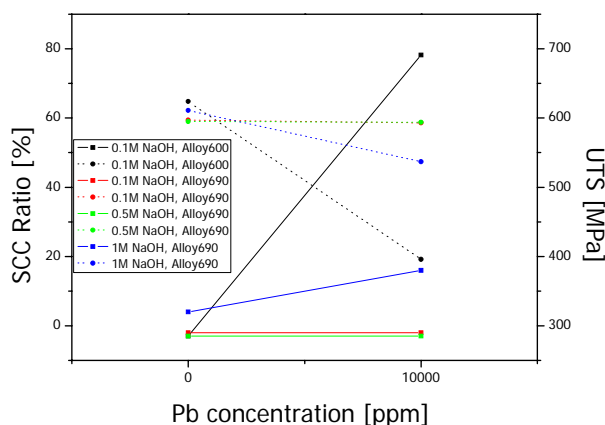


Fig. 1. Effect of the Pb content on the SCC susceptibility of Ni-based alloys.

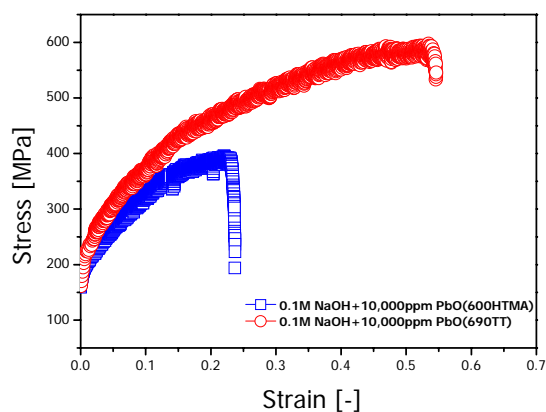


Fig. 2. Stress-strain curves of Ni-based alloys in Pb-containing 0.1M NaOH solution.

Table 1 Chemical compositions of Alloy 600 HTMA (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 Chemical compositions of Alloy 690 TT (wt %)

Material	C	Si	Mn	P	Cr	Ni	Fe	
Alloy690	0.0	0.2	0.32	0.009	29.57	58.9	10.54	
	2	2						
Material	Co	Ti	Cu	Al	B	S	N	Nb
Alloy690	0.0	0.2	0.01	0.019	0.004	0.00	0.017	0.01
	1	6			1			

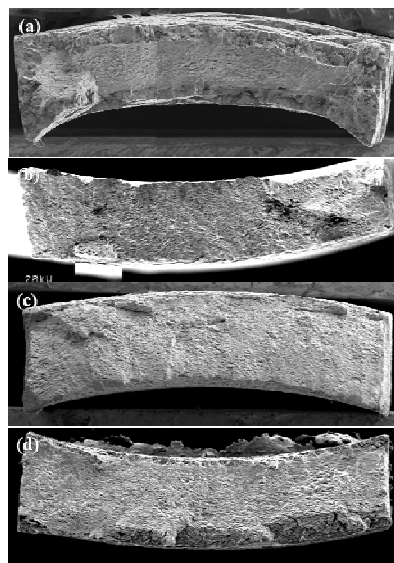


Fig. 3. SEM images showing the fracture surface of Ni-based alloy. (a) 0.1M NaOH + 10000ppm PbO (Alloy 600HTMA), (b) 0.1M NaOH + 10000ppm PbO (alloy 690TT), (c) 0.5M NaOH + 10000ppm PbO (alloy 690TT), and (d) 1M NaOH + 10000ppm PbO (Alloy 690TT).