Transactions of the Korean Nuclear Society Spring Meeting
Gwangju, Korea, May 30-31, 2013

New Technology for Corrosion Mitigation of Steam Generator Tubesheet in Secondary Side Environments

Do Haeng Hur*, Myung Sik Choi, Deok Hyun Lee, Jung Ho Han
Korea Atomic Enery Research Institute, 150 Deokjin-dong, Yuseong-gu, Daejeon, 305-353, Korea
**Corresponding author: dhhur@kaeri.re.kr*

1. Introduction

Denting is a phenomenon that a steam generator tube is distorted from the outer surface to the direction of the inner by a volume expansion of corrosion products of tube support materials adjacent to the tube [1]. Since denting imposes slow straining on the tube, it accelerates stress corrosion cracking on both the primary and secondary sides of the tube. Therefore, it has been a precursor of stress corrosion cracking. Although denting has been mitigated by a modification of the design and material of the tube support structures, it has been an inevitable problem in the crevice region of the top of the tubesheet(TTS) [2].

Denting at the TTS has been a significant concern regardless of the tube materials [3]. This is because it is a mechanical process resulted from a volume expansion of corrosion products of the tubesheet materials. It should be noted that the corrosion rate of low alloy tubesheet materials is accelerated due to the presence of corrosion products accumulated at the top of the tubesheet. Therefore a reduction of the corrosion rate of the tubesheet material should be a key strategy to prevent tube denting at the TTS as well as an improvement of the secondary water chemistry.

This paper provides a new technology to prevent denting by cladding the secondary side surface of the tubesheet with a corrosion resistant material. In this study, Alloy 690 material on the surface of the SA508 tubesheet was cladded to a thickness of about 9mm. The corrosion rates of the SA508 original tubesheet and Alloy 690 clad material were measured in acidic and caustic simulated environments.

2. Experimental Methods

Forged low alloy steel, SA508 was used as a tubesheet material. Alloy 690 material on the secondary surface of the tubesheet was cladded to a thickness of about 9mm.

Corrosion coupons were made by cutting the Alloy 690 clad layer and SA508 tubesheet, respectively, to a dimension of 25mm x 45mm x 1mm thickness. Specimens were ground using silicon carbide paper down to grit 600, ultrasonically degreased in acetone, and finally weighed.

Corrosion rates measurements were made in two different environments; 0.1M $NiCl_2$ solution at 300℃ for 150h and 2M NaOH solution at 315℃ for 500h. The secondary side surface of the tubesheet during the operation period is always covered with sludge. To simulate this condition, some coupons were also located within the magnetite sludge pile. The particle size and purity of the magnetite was about 1 ㎛ and 99%, respectively.

3. Results and Discussion

3.1 Corrosion in acidic Environments

Fig. 1 shows the corrosion rates measured in 0.1M $NiCl_2$ solution for 150h. Both test materials indicated a weight loss. When exposed to the solution, the corrosion rates of SA508 and Alloy 690 clad were 0.873mg/cm^2h and 0.00163mg/cm^2h, respectively. Within the magnetite sludge pile, the corrosion rate of SA508 was 2.06mg/cm^2h, while that of the Alloy 690 clad drastically decreased to 0.00303mg/cm^2h. This means that the corrosion resistance of the tubesheet was improved by a factor of 540~680 by the Alloy 690 cladding. On the other hand, the corrosion rates of the two materials inside the magnetite increased by about 2-fold, compared to those in the solution. Nevertheless, the effect of Alloy 690 cladding on the corrosion prevention was more prominent in the corrosive environment of the sludge pile.

Fig. 2 shows the cross sectional surface of SA508 and Alloy 690 clad located inside the magnetite pile. Laminated denting oxide was formed in SA508, but no oxide layer was observed in the Alloy 690 clad.

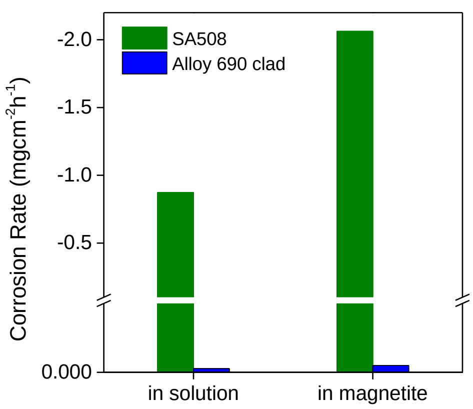
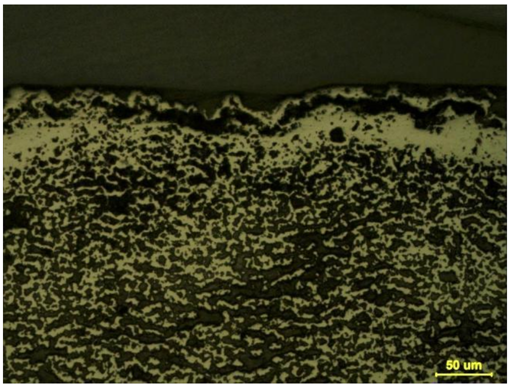
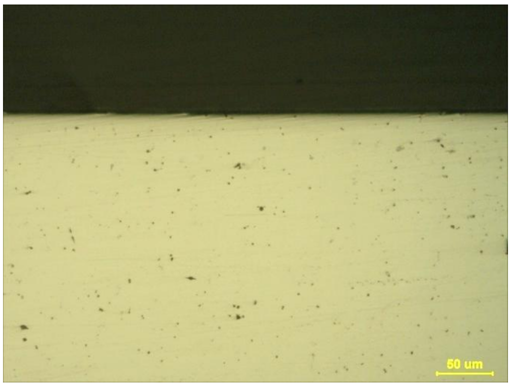


Fig. 1. Corrosion rates of SA508 and Alloy 690 clad material in 0.1M $NiCl_2$ solution at 300℃.



(a) SA508



(b) Alloy 690 clad

Fig. 2. Cross section of SA508 and Alloy 690 clad after 150h in 0.1M $NiCl_2$ solution at 300℃.

3.2 Corrosion in alkaline Environments

Fig. 3 shows the corrosion rates measured in 2M NaOH solution for 500h. SA508 indicated a weight loss, while Alloy 690 clad showed a slight weight gain. When exposed to the solution, the corrosion rates of SA508 and Alloy 690 clad were 0.0070mg/cm^2h and 0.00024mg/cm^2h, respectively. Within the magnetite sludge pile, the corrosion rate of SA508 was 0.019mg/cm^2h, while that of Alloy 690 clad drastically decreased to 0.00033mg/cm^2h. That is, the corrosion resistance of the tubesheet was improved by a factor of 29~58 by the Alloy 690 cladding. Similar to the result in an acidic environment, the corrosion prevention performance of the Alloy 690 cladding was more effective in the corrosive environment of the sludge pile.

4. Conclusions

Denting has been a precursor of stress corrosion cracking in nuclear steam generator tubing, although it may be mitigated by a design and material modification of the tube support structures and secondary water chemistry control. Corrosion resistant Alloy 690 tubing is not an exception because denting at the TTS is due to corrosion of the tubesheet material. In this paper, a new technology was suggested to prevent denting at the TTS by cladding the secondary side surface of the tubesheet with a corrosion resistant material. It was verified that the corrosion rates of a tubesheet with an Alloy 690 clad layer drastically decreased in both acidic and alkaline environments, even inside the magnetite sludge pile.

Because the cladding processes of Alloy 690 have already been applied to the primary side surface of a tubesheet in commercial steam generators, the applicability of this technology is considered very high.

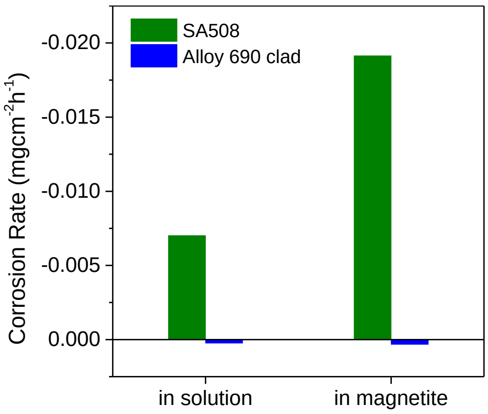


Fig. 3. Corrosion rates of SA508 and Alloy 690 clad material in 2M NaOH solution at 315℃.

REFERENCES

[1] J.P.N Paine, Steam Generator Reference Book, Rev.1, Vol.1, pp.8-1, 1994.
[2] R.W. Staehle and J.A. Gorman, Quantitative Assessment of Submodes of Stress Corrosion Cracking on the Secondary Side of Steam Generator Tubing in Pressurized Water Reactors: Part 1, Vol.59, No.11, p.931, 2003.
[3] H.M. Feldman, Proceeding of SGMP KHNP/EPRI Workshop, pp.95, 2011.