Comparison of TiO_2 Penetrations into Open and Packed Tubesheet Crevices

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1. Introduction

Degradation of alloy 600 tubing of a steam generator by IGA/SCC has been observed in flow restricted regions where impurities such as sodium in the bulk water can be concentrated by a boiling to an extreme pH. Titanium dioxide is used as an inhibitor to mitigate a tube corrosion under a caustic condition [1]. CASS (Crevice Chemistry Analysis and Simulation System) with a HT/HP (High Temperature/High Pressure) was used to investigate a inhibitor penetration into a tube in open/packed crevices.

After the boiling concentration for about 24 hours in open/packed crevices with a feed solution composed of TiO_2 with 40 wppm NaOH, titanium penetrations into the crevices were observed by an Auger analysis and were compared.

2. Experimental

2.1 Loop for penetration tests

CASS has been developed to simulate a real tubesheet crevice of a steam generator [2]. CASS has two main loops: a primary water loop and a secondary water loop with operating conditions as shown in Table 1.

Table 1. Operating conditions

	Primary side	Secondary side
Temperature	285	265
Pressure (MPa)	11	5.1
Flow rate (L/hr)	2300	2
Water chemistry	H_2O	$NaOH/TiO_2$
Environment	Reducing	Reducing

2.2 Tube support ring and heat transfer tube

A crevice section which has a 0.15 mm gap and a 40 mm depth is schematically described in Fig. 1. The CASS was instrumented with thermocouples and electrodes for a measurement of the Electro-Chemical Potential (ECP) in the crevice and bulk water.

The tube was Alloy 600/UNS N06600, Heat #770177, supplied by Sandvik steel, having the following composition (in weight percent): Ni 74.19, Cr 15.52, Fe 9.30, Ti 0.29.

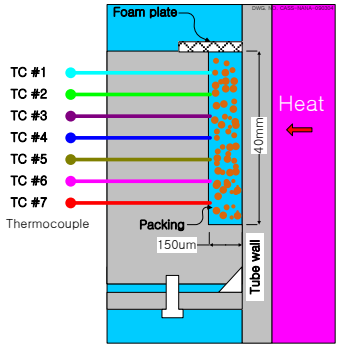

Fig. 1. Schematic diagram of tube support ring.

2.3 Packing materials

To simulate a packed crevice with sludge, the tubesheet crevice was packed with diamond grit which have two different size groups: a 100/120 mesh (125 ~ 150 μm) and a 170/200 mesh (75 ~ 90 μm) with the weight ratio as one to one. The packing density was 3.82g/cm^3.

3. Results and discussion

The secondary water storage tank, made of titanium, was deaerated with 4% hydrogen gas (argon balanced). Degussa P25 TiO_2 was used for the penetration experiments, which has an average size of 857nm. The secondary water containing titanium dioxide, 40 wppm NaOH, and 0.15 wppm H_2 was pumped by a diaphragm pump and drained through a back pressure regulator [2]. Flow rate of the secondary system was maintained at 2 L/hr.

The primary water was maintained at a constant temperature of 285℃. The secondary pressure was maintained at 5.08 MPa which corresponds to the saturation temperature of 265℃ so that a boiling could occur. In this work, the difference between the primary water temperature and the secondary saturation temperature represents the available superheat, ΔT. The experiment for a titanium penetration into a crevice was performed at ΔT = 20℃.

In order to investigate the penetration of TiO_2 into the crevice, the tube was pulled up from the vessel after the boiling concentration and divided into eight specimens with an 8mm length as shown in Fig. 2. Each specimen was washed for an Auger electron spectroscopy.

Fig. 3 shows the maximum titanium concentration of the specimens at different positions in a packed crevice after about a 24 hours boiling at ΔT = 20℃ with a 1 wppm Ti feed solution as Degussa P25 TiO_2.

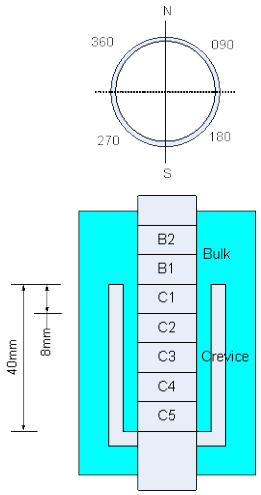

Fig. 2. Number and orientation of specimens.

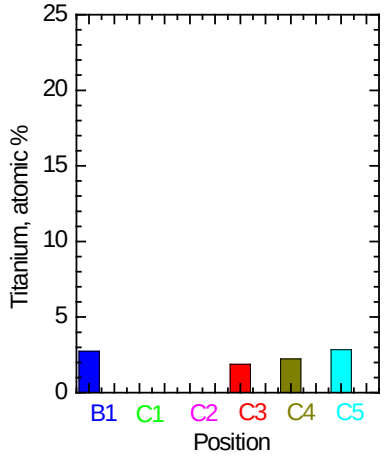

Fig. 3. Maximum titanium concentration in oxide layer with 1 wppm Ti feed as Degussa P25 and a packed crevice.

Ti concentrations at positions C1 and C2 were not found to have a tube scratch when it was pulled out. But the 2 ~ 3 Ti percents of the specimens at other positions were higher than 0.29%, Ti percent of the base metal, alloy 600/UNS N06600. It means that a titanium penetration occurs into alloy 600 tube in a packed crevice.

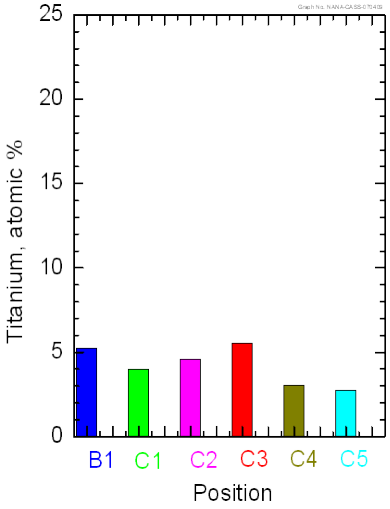

Fig. 4. Maximum titanium concentration in oxide layer with 1 wppm Ti feed as Degussa P25 and an open crevice.

Fig. 4 illustrates the Ti concentration of the specimens after the penetration experiment in an open crevice under the same condition as in Fig. 3. Ti Atomic percents of the specimens with an open crevice were much higher than those with a packed crevice as shown in Fig. 3.

4. Conclusions

Penetration experiments of titanium dioxides into an alloy 600 tube in open/packed crevices with a 0.15mm gap were carried in the CASS (Crevice Chemistry Analysis and Simulation System).

After about 24 hours of a boiling at a superheat of 20℃, the maximum titanium concentrations in the oxide layers of the tube specimens in an open crevice were lower than the ones in a packed crevice, but those were much higher than 0.29%, Ti concentration of the base metal of the tube.

REFERENCES

[1] J. Daret, J. P. Paine, and M. Partridge, “Model Boiler Testing to Evaluate Inhibitors for Caustic Induced Stress Corrosion Cracking of Alloy 600 Tubes”, Proc. 7th Int. Symp. Environmental Degradation of Materials in Nuclear Power Systems-Water Reactors, Breckenridge, CO, p. 177, 1995.

[2] J. W., Na, U. C., Kim, and W. Y., Maeng, “Comparison of a Penetration in Different Sizes of Titanium Dioxides into a Tubesheet Crevice”, Trans. of Korean Nuclear Society Spring Meeting, Jeju, 2008.