Corrosive Wear Test of Alloy 690 in Water Chemistry Environment at Room Temperature

Seung Mo Hong, Changheui Jang, Sang Gyu Lee, In Sup Kim
Department of Nuclear and Quantum Engineering
Korea Advanced Institute of Science and Technology
373-1 Guseong-dong, Yuseong-gu, Daejeon 305-701, Republic of Korea
prince540@kaist.ac.kr

1. Introduction

The various kinds of degradation phenomena that may occur in the steam generator are affected by thermal hydraulics and a number of corrosion processes. Most utilities operate their units on all volatile treatment (AVT) chemistry, where the pH is controlled by adding an adequate amount of chemicals to the bulk water [1]. During the operation water flow induces the tube vibration in the U-bend region of steam generator tubes known as the flow induced vibration. The flow induced vibration causes wear damage on the steam generator tubes against their support structures, and the wear and corrosion combined action results in mutual reinforcement. The interaction among abrasion, rubbing, impact and corrosion can significantly increase total material losses, especially in aqueous environment [2]. The effect of wear on corrosion was founded to be related to the recovery rate of passive films broken by scratching [3]. And the pure abrasion rate increased with decreasing pH [4].

In the present study, to examine the effect of pH, work rate and time, the oscillation wear tests were performed in room temperature with steam generator tube material (Alloy 690) against the anti-vibration bar material (409SS).

2. Experimental procedure

2.1 Experiment rig and test specimen

Alloy 690 TT was used as wear test material against 409 stainless steel. The as-received materials of alloy 690 TT were cut to cylinders of 12 mm in length and 19 mm in diameter. Table 1 shows the density, the chemical compositions and the mechanical properties of alloys [5, 6].

The test rig was constructed for the oscillation wear test between the steam generator tube and the anti-vibration bar (AVB) in water chemistry. Steam generator tube specimen was installed at oscillation motion part, and AVB specimen was attached at normal load applied part. Test environments were aerated distilled water and NaOH solution. NaOH is known to effective chemical for the pH control test of Alloy 690.

2.2 Test procedure

The experiment was performed with a sliding motion. Loading Frequency of 20 Hz was chosen for the test since it was reported that there is apparently no effect of frequency on wear in the 20 – 35 Hz range [7]. The sliding amplitude was 350 ㎛ and the normal load was set to 20 to 150 N. The test time was 10^5 cycles and 3×10^5 cycles.

The wear rate was estimated by measuring the weight loss of specimen before and after the experiment. The specimen was cleaned with acetone in the ultrasonic cleaner and dried with compressed air. To reduce the measurement error, specimens were measured 5 times and standard weight was used before weight measuring.

3. Results and discussions

3.1 Potentiodynamic Test results

At pH 7, corrosion potential of the Alloy 690 was -0.6 V of SHE and corrosion current density was 10^{-6} A/cm^2. At pH 13, corrosion potential was decreased to -1.3 V of SHE and corrosion current density was increased to 10^{-4} A/cm^2. It shows that the wear mechanism is changed at high pH region. For the corrosive wear, total wear damage is sum of mechanical wear damage and oxide film broken damage [3]. At high pH, chromium oxide is dissolve to CrO_2^- [8]. This means that the oxide composition of the Alloy 690 at pH 13 was changed from that at pH 7. The composition change of the chromium oxide can have an effect to the oxidation rate of Alloy.

Table 1. Chemical compositions and mechanical properties of test specimens

	Cr	Fe	C	Si	Mn	Ti	P	S	Co	Ni	T.S. (Ksi)	Y.S. (Ksi)	Density (x 10^{-9} mg/㎛ ^{3})
Alloy 690	16.81	9.1	0.026	0.32	0.81	0.35	0.008	0.002	0.012	Bal.	80 min.	35 min.	7.817
409SS	10.5-11.75	Bal.	0.08	1.00	1.00	6 x % C	0.045	0.045	-	-	-	-	-

3.2 Oscillating wear test results

Figure 1 and figure 2 show the wear rate against the work rate at pH 7 and pH 13, respectively. The wear coefficient at pH 13 was about ten times greater than that at pH 7. This deference shows that the wear resistance of the Alloy 690 decreases at high pH solution. Figure 3 shows an effect of test time on wear rate at pH 7. The wear coefficient of 3 x 10^5 cycles test was decreased about 50% than that of 10^5 cycles. It shows that wear rate is decreased with time. The decreasing in wear rate with time would be attributed to the change in roughness of specimen or sub layer of the worn surface with time. Figure 4 shows the worn surface of Alloy 690 at pH 7.

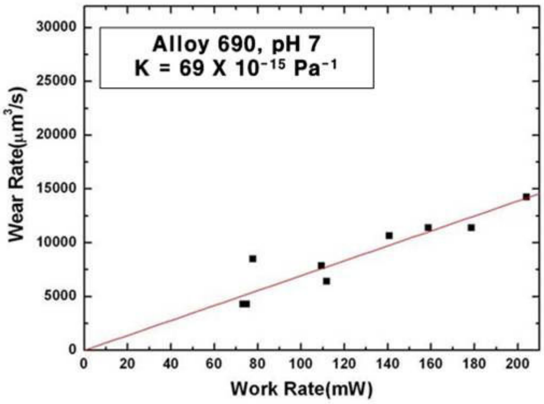

Figure 1. Wear rate against work rate of Alloy 690 on 409 SS at pH 7.

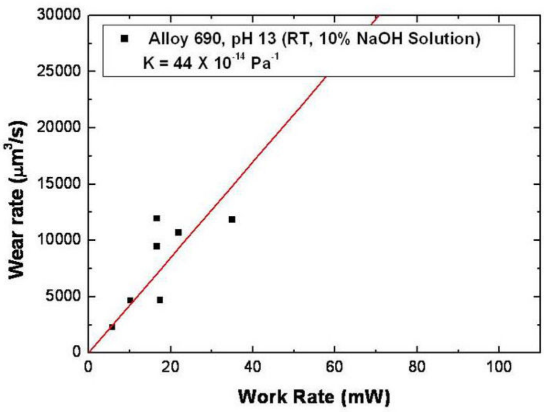

Figure 2. Wear rate against work rate of Alloy 690 on 409 SS at pH 13.

4. Conclusion

The oscillation wear tests of Alloy 690 on 409 SS were performed at the water chemistry condition. The wear coefficient was increased about ten times at pH 13 than at pH 7. And wear coefficient was decreased with test time.

Acknowledgement

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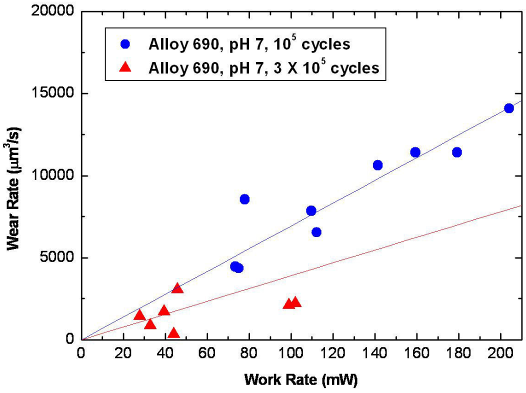

Figure 3. Test result for time effect of Alloy 690 on 409 SS.

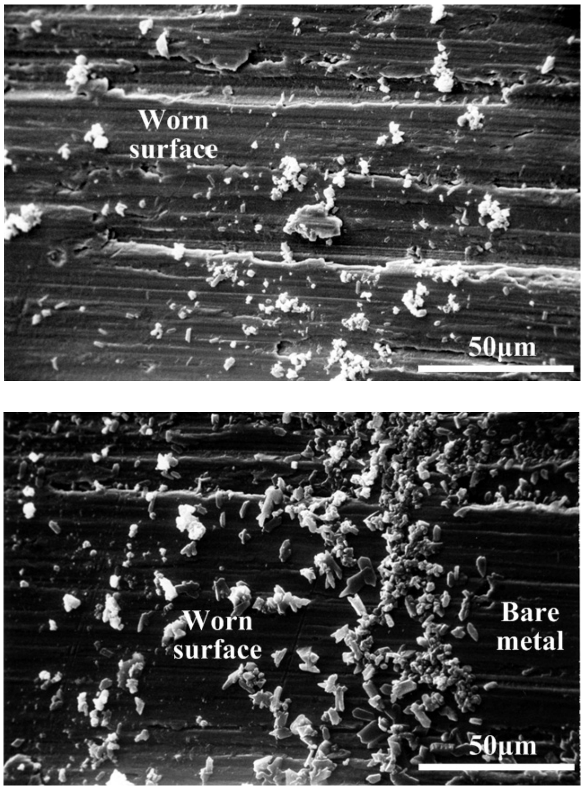

Figure 4. Worn surface observation of Alloy 690 at pH 7.

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