A Study on Corrosion and Fretting Wear Resistance of Alloy 690 Tubes

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1. Introduction

Alloy 690 is broadly used as a material of nuclear power plant's steam generator tubes because of its excellent mechanical strength, corrosion properties, wear properties and stability at a high temperature. However, the tubes for nuclear power plant's steam generators become a major threat for lifetime management and efficient operation of nuclear power plant due to various corrosion and fretting wear failures caused by flow-induced vibration (FIV) that occurs between tubes. In this article, the effects of such failures have on the materials of alloy 690 are assessed.

2. Experimental

2.1 Specimen preparation

The specimens used in the experiment consist of alloy 690 tube type, which is used for nuclear power plant's U tube steam generator and Stainless steel 409 plate type which is used for the spacer grid

2.2 Corrosion Test

For more rapid corrosion that meets the extreme conditions of steam generator tube in nuclear power plants, the corrosion test was performed in an autoclave using water of 220ppm LiOH, under a pressure of 10.3MPa, for corrosion times up to 15days and at a temperature of 350℃.

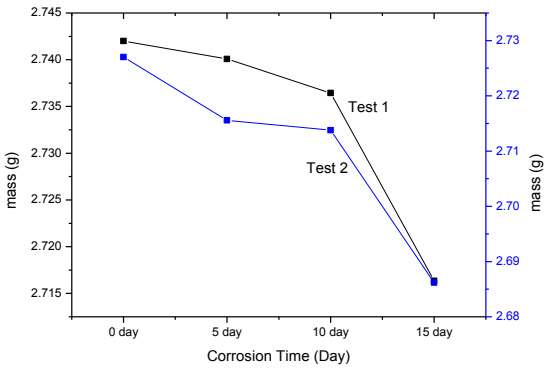

Fig.1 The effect of corrosion time on alloy 690 mass decrease at 350 ℃ under LiOH 220ppm water condition.

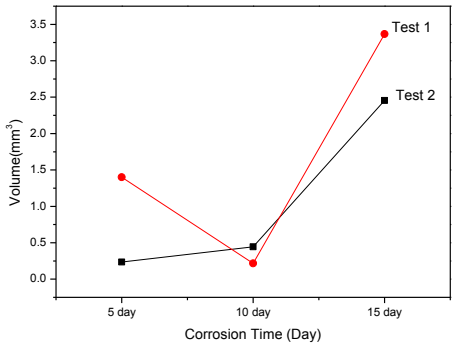

Fig 2. The effect of corrosion time on alloy 690 volume difference increase at 350 ℃ under LiOH 220ppm water condition.

Figures 1and 2 show the effect of time on the changes in the mass and volume of alloy 690. For the volume change method, we divided mass, which came from before and after the experiment, by density to calculate the volume. In general, volume and mass will decrease continuously as time goes. However, the oxide volume changes in an irregular pattern since the oxide formed on the alloy 690 metal may be detached due to the flake formation.

2.3 Fretting Wear Test

The fretting wear tests were performed using a sliding amplitude of 1mm, vertical loads of 20N an 30N and 20Hz for 6, 12, 18 and 24 hours at room temperature. The steam generator tubes, made of alloy 690 were used as the test specimens. And the grid plates made of stainless steel 409 were also used as the alloy tube contacting plate. The amount of the fretting wear increased with time, as shown in figures 3 and 4. From these figures, it can be seen that figures the wear rate increased with time and reduced at the later time.

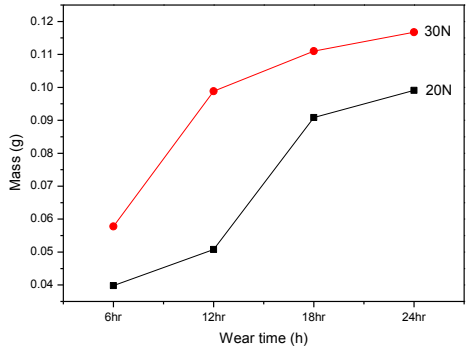

Fig.3 Wear time dependence on mass (gain) formed on alloy 690 in room temperature 20N, 30N.

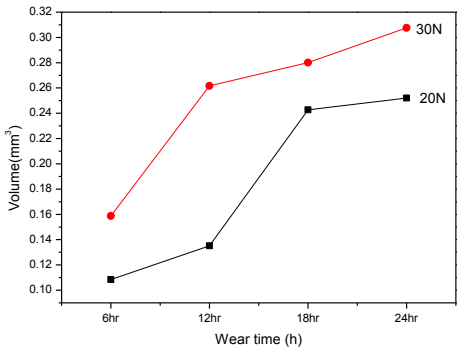

Fig.4 Fretting wear behaviors of Alloy 690 at 350℃ under LiOH 220ppm water condition.

2.4 Tensile Test

Tensile test was implemented to see the tensile properties according to the amount of corrosion of the material of the alloy 690, which is mechanically excellent. The tensile tester of Instron 8502 was used in this test and tensile speed was set to be 0.12mm/min. Then, the tensile tests were performed at room temperature using ring specimens that were corroded in the autoclave.

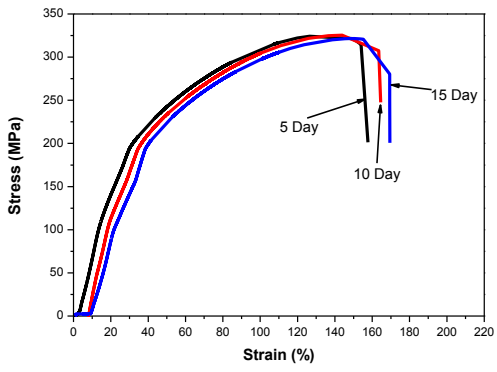

Fig.5 Tensile test results at room temperature

Table I: Tensile test results at room temperature

	Stress(MPa)	Strain(%)
5 Day	324	99
10 Day	325	110
15 Day	321	114

From the results of the tensile tests, stress-strain curves were generated. The test results show that the ductility increased as corrosion time increases. From the fracture surface images of SEM (Figure 5), however, it can be clearly seen that even the tensile tested specimen at day 15 generated somewhat ductility.

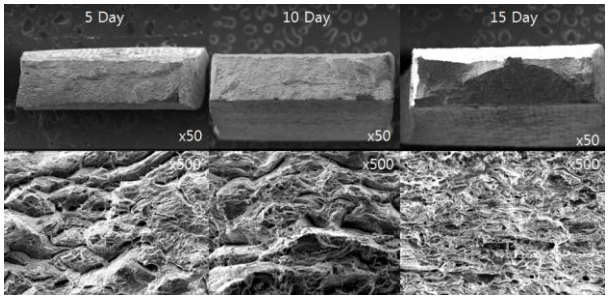

Fig.5 SEM micrographs of Alloy 690 after tensile tests

3. Results and Discussion

The amount of corroding mass decreased slowly with time, and then it rapidly declined on day 15. According to this, volume variation was low on day 10 and it recorded high on day 15. From this result, we can expect that oxide layer came away while corroding. The wearing mass and volume increased when wear time and stress increased. Therefore, we can see that ductility increased with time, and the characteristics of wear affect mechanical properties of the materials.

4. Conclusions

The corroded volume variation and mass decreased continuously with time. However, the oxide volume changes in an irregular pattern since the oxide formed on the alloy 690 metal may be detached due to the flake formation. The amount of the fretting wear increased with time. It can be seen that the wear rate increased with time and reduced at the later time. The test results show that the ductility decreased as corrosion increases.

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