Transactions of the Korean Nuclear Society Spring Meeting
Pyeongchang, Korea, May 27-28, 2010

Fretting Wear Experiments between the Same Alloy 690 Materials for Conservative Wear Evaluation of Steam Generator Tube

Jeong-Keun Lee [a*] and Chi-Yong Park [a]
[a]*Nuclear Power Lab., KEPRI, 103-16, Munji-Dong, Yuseong-Gu, Daejeon, 305-380, KOREA*
[*]*Corresponding author: hisfy012@kepri.re.kr*

1. Introduction

Steam generator tube's wear damage generated by the remained material or the tube support plate due to flow induced vibration is important on the maintenance and inspection fields of steam generator (SG) tubes in the nuclear power plants. Worn tube was evaluated by the wear evaluation method. Understanding of tube wear characteristics is also very important to keep the integrity of the steam generator tubes. And, it may give to insight the maintenance engineer for decision about reaching the plugging criteria. In this study, test material pairs were selected as alloy 690 tubes against the alloy 690 plate materials. It has been known that the same material fairs will give a conservative wear coefficient. When wear coefficients is used in predicting life time and integrity for the wear damaged tube, a conservative wear coefficient will give the overestimating wear volume. Investigation of worn surfaces will also give insight for the worn tube in the plant fields.

2. Experiments and its Systems

In this section, experimental method and test system used in performing fretting wear tests are described.

2.1 Wear Test System and Conditions

The test system[1] for this experimental wear study consists of an environmental chamber, an actuator which is divided into a cyclic impact loading device and a reciprocating motion generator part, a water loop system simulating environments of secondary side of a SG in a nuclear power plant, and a control unit and program. In the high temperature and high pressure test, the temperature of the pure water is over 280°C in the chamber. To simulate and investigate impact fretting wear of SG tubes, test system as shown in Fig.1 have been used to control very small displacement of sliding motion and impact forces. Test system could be operated under plant operating conditions such as pressure of 15MPa, high temperature of 290°C and low dissolved oxygen under 5ppb.

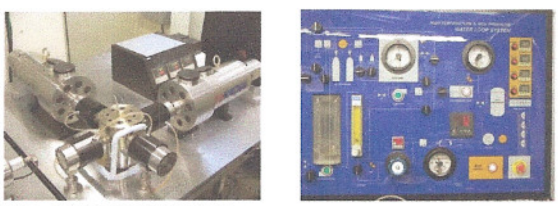
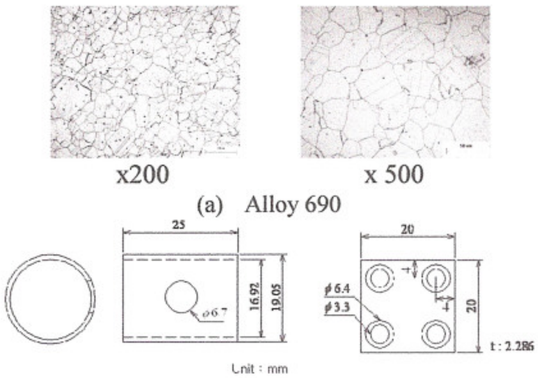


Fig. 1 Wear test system

Alloy 690, which is a tube material of replaced SG, was used for tube specimens. Alloy 690 plate specimen as a representing material about foreign or stainless steel support plate was also prepared. Specimen shape and microstructure were shown in Fig.2



(a) Alloy 690 (b) Specimen Shape
Fig. 2 Microstructures of Alloy 690 and Specimen Shape

Tests were performed in the water environment at the temperature of 290°C. Pressure is about 15MPa and N_2 gas was charged in distilled water. Reciprocating sliding distance is from 0.04mm to 0.21mm at a frequency of 11Hz. The applied normal load ranges from 20N to 50N at a frequency of 10Hz.

2.2 Reliability Check of Wear Test Process

The wear test process was inspected during the test period with 12 hours. The inspection included examination of the control monitor and the loop operation to monitor parameters such as the operating pressure, the operating temperature and the oxygen level. If abnormal operation of test facility would be detected, appropriate action such as process stop or discard of results data has to be done. For obtaining the sound wear test results, the process reliability has to be checked from the process information such as global peak force and work rate variation during the full test time, which sample is shown Figure 3.

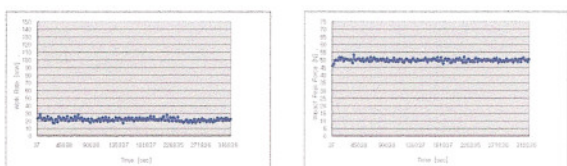


Fig. 3. Process Reliability Check (Force and Workrate)

The second checking method for sound wear test process is investigating the photo of the worn surface of tube and support specimen. Examination of the worn surface reflects the tightness of the fit between the jig and the test specimen and possible abnormal operation of the movement. In Figure 4, a worn surface is presented for a tube specimen. Figure 5 shows a worn specimen for alloy 690 material.

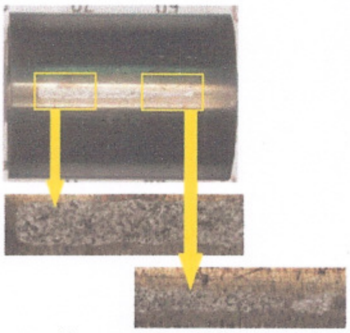


Fig. 4. Worn surfaces of alloy 690 tube

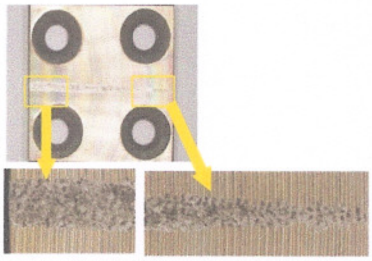


Fig. 5. Worn surfaces of alloy 690 plate material

3. Results and Investigation

For obtaining insight into wear phenomenon through an investigation of the surface of the worn tube in the plant fields, photos of worn surfaces are presented. Wear coefficient of tubes were gained for evaluating the prediction of wear damage.

3.1 Worn Surfaces

The worn surface was examined through a scanning electron microscope (SEM) for the purpose of obtaining insight about the general worn surfaces in the case of withdrawing a damaged tube from the steam generator. Figure 6 shows the worn surfaces of a piece of alloy 690 tubing (force of 20N and distance of 0.09mm). The worn surfaces and microscopic characteristics of alloy 690 plate also are shown in Figure 7. Worn surface pattern and micro-photo are the same for alloy 690 tube and plate. From macroscopic examination, impact fretting pattern including local sliding is known easily at almost worn area.

3.2 Wear Coefficients

The wear coefficient will be used to estimate the remaining life of a steam generator tube by modeling due from the tube supports or foreign objects using the wear rate model.

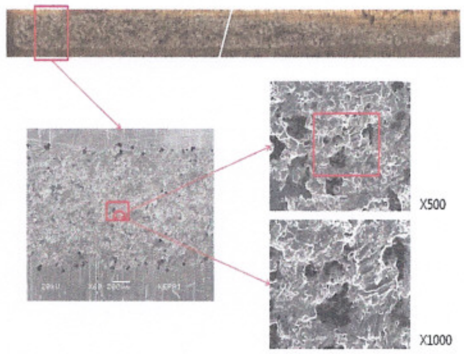


Fig. 6. Worn surface of slloy 690 tube against alloy 690 plate by fretting wear

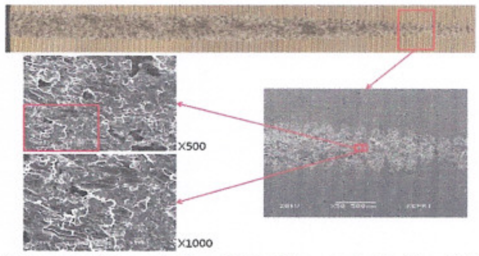


Fig. 7. Worn surface of alloy 690 plate against alloy 690 tube by fretting Wear

Figure 8 shows the relation of work rate with wear rate for alloy 690 tubing against alloy 690 plate, which is selected as a kind of conservative material considering the wear characteristics. The wear rate was calculated from the wear volume which is converted from the measured worn weight. From the relation between work rate and wear rate, the wear coefficient of alloy 690 tubing against same material is obtained as average 91.58×10^{-15} Pa^{-1}. The wear coefficient ranged from 52.71×10^{-15} Pa^{-1} to 128.56×10^{-15} Pa^{-1}. In the calculation of tube life prediction, selection of the average or maximum value may depend on the user.

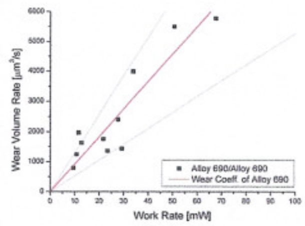


Fig. 8. Wear coefficient graph of alloy 690 tube

3. Conclusions

The wear coefficients were obtained and some worn surfaces are presented from fretting wear test of SG alloy 690 tube against alloy 690 same material.

REFERENCES

[1] C. Y. Park, Y. S. Lee and M. H. Boo, Development of Wear Test System for Steam Generator Tubes in NPP, Key Engineering Materials, Vol.297-300, p. 1418, 2005.