Impacting Wear Behavior of Spring-Supported Tubes in High Temperature Distilled Water

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1. Introduction

Fretting-related degradations due to FIV have been concentrated on the major components of nuclear power plants such as the fuel rods, steam generator tubes and control rods. Especially, in the case of the nuclear fuel rod, the wear mode could be changed from a sliding wear (existence of a contact force) to an impact/sliding wear (existence of a gap) because the spacer grid materials degraded due to the neutron irradiation effect and the high temperature environment. To improve the reliability of the nuclear fuel, the impacting wear behavior should be examined in actual operating conditions even though it is difficult to define the exact contact condition between the fuel rod and the spacer grid spring. Also, there has been little effort made to examine the impacting wear behavior of the nuclear fuel rod. The objective of this study is to examine the impacting wear behavior of the nuclear fuel rod against the spacer grid spring in high temperature distilled water.

2. Experimental Procedure

In this study, the fuel rod specimen is cut from the straight rod and the springs are fabricated by pressing and punching a Zirconium alloy with a thickness of 0.46 mm. A high temperature and pressure impact/sliding wear tester was developed to simulate the fuel fretting phenomena in a nuclear power plant environment (above 320℃, 15 MPa) [1]. The fuel rod specimen oscillates with a range (peak-to-valley) of 40 ~ 100 μm at a frequency of 30 Hz. A maximum impact load was set at 10 N with the range of 360 μm at a frequency of 30 Hz. Besides the tests for room temperature(RT), high temperature wear tests were carried out up to 10^5 cycles in distilled water(300℃, about 88 kgf/cm^2). After the tests, the wear volume and worn area of the fuel rod specimen were measured using a surface roughness tester, optical microscope and SEM.

3. Results and Discussion

3.1 Wear Volume

After the impacting wear tests, the average wear volume was evaluated and is shown in Fig. 1. Wear volume increased with increasing slip amplitude and this behavior is in good agreement with the previous results [2,3]. From the results, it is apparent that the critical slip amplitude below which the wear volume was not detectable is about 40 μm in high temperature water. Even though it is difficult to define the critical slip amplitude in a high temperature condition due to the relatively smaller wear volume, the increasing trend of the wear volume was quite similar to the reference data (room temperature water) as shown in Fig. 1. These small wear volumes in a high temperature water seem to be related to the formation of wear particle layer and a variation of the spring characteristics.

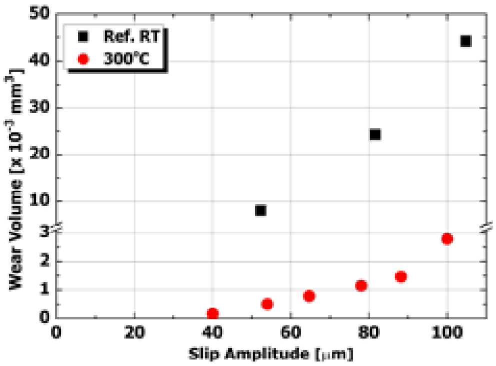

Figure 1. Variation of the wear volume with increasing slip amplitude in both room and high temperature water.

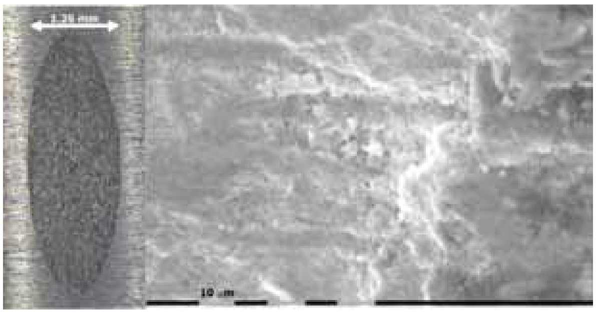

Figure 2. Results of the worn surface observation using optical microscope in RT and SEM in room and high temperature water.

3.2 Worn Area Observation

To evaluate the wear mechanism on the worn surface, the worn surfaces were observed using optical microscope and SEM and the results are shown in Fig. 2. The generated wear particle layers in the room temperature water were rapidly fractured and disappeared by increasing the slip amplitude. But well-developed wear particle layers also appeared in the high temperature water and it is easy to detect the evidence of the removed particle layers. So, the lower wear volume in high temperature water is associated with these barriers restraining a further wear process. However, it is not enough to say that the lower wear volume in high temperature water was entirely due to the wear particle layers on the worn surface. Because it is expected that the wear particle layers could not accommodate a severe strain and deformation between the contacting surfaces under an impacting load.

3.3 Temperature and Wear Scar Size

Above all, the spring characteristics are changed with increasing temperature and this also could vary the wear behavior between the contact surfaces. But, it is difficult to examine a dynamic response when an impacting load is applied in the high temperature water condition. So, the wear scars after the wear tests were examined and compared with the room temperature condition. Fig. 3 shows the relationship between the length and width of the elliptical wear scar and good linearity in room temperature water, but it shows a considerable scattering of the values in high temperature water. This result indicates that the wear damage was less dominant in the direction of length (i.e. slip direction) and the actual slip displacements between the contacting surfaces are expected to have lower values in high temperature water.

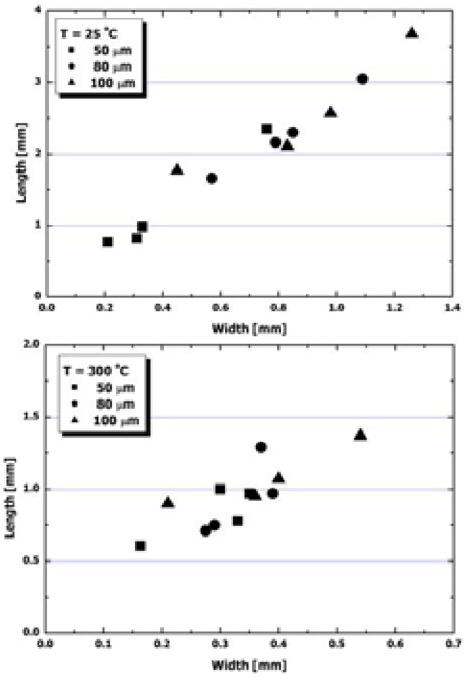

Figure 3. Variation of wear scar length and width in room and high temperature water.

4. Conclusion

Impacting wear tests were performed by using nuclear fuel rods against spacer grid springs in high temperature distilled water. From the results, the following conclusions are drawn.

(1) With increasing slip amplitude, the wear volume also increased in both the room and high temperature water.
(2) The lower wear volume in high temperature water is partially associated with the wear particle layers restraining any further wear process
(3) The wear damage was less dominant in the slip direction and the actual slip displacements between the contacting surfaces are expected to have lower values in high temperature water.

ACKNOWLEDGEMENTS

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