Analysis of Contacting Behavior between a Fuel Rod and Spring/Dimple in a Simulated Fretting Wear Tester

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1. Introduction

Up to now, a grid fretting problem has not been sufficiently investigated enough to apply the examined fretting mechanism to the development and design of spacer grid shapes. In previous studies, fretting wear experiments have been performed with unit part of various types of spacer grid spring/dimple in room temperature air and water [1,2]. One of the most important results is that the contacting force (normal load) was gradually decreased with increasing cycle, which depended on the slip amplitude, the initial normal load and the contacting spring shape. When considering the actual contact condition, a decrease of the contacting force exerted on the fuel rod by elastic deformation of the spring results in the variation of the contacting force between the fuel rod and dimple that were located in the opposite side. So, it is necessary to perform the unit cell experiments in order to evaluate the fretting wear performance of developed spacer grids. In this study, a new type of fretting tester was developed for the simulation of the actual contact condition between the fuel rod and springs/dimples (i.e. 1x1 unit cell). The objectives of this study are to analyze the characteristics of the developed fretting tester and to evaluate the contacting behavior between fuel rod and springs /dimples during the rod was vibrated with a elliptical motion.

2. Development Procedure

2.1 Vibration Mechanism

In order to simulate the actual contact condition between the fuel rod and spring/dimple at the 1x1 unit cell, a vertical type of fretting test rig is specially designed for the present study. A schematic view of the tester is shown in Fig. 1. A dc servomotor is equipped at the top region and connected to the eccentric cylinder with a flexible motor coupling. Four rollers that were arranged with 90^{o} are in contact with the cylinder. Therefore, the circular motion range of the tube could be varied from 300 ~ 500 μm by adjusting the position of four rollers. The outer diameter of the fuel rod that could be attached in this tester is free from restraint when considering an annular fuel that is expected to have a larger size compared with a commercial PWR fuel rod (i.e. 9.5mm).

2.2 Measurement of force and displacement

In this tester, six non-contact displacement sensors and four biaxial load cells were attached for measuring the displacements and the contacting forces. Two displacement sensors were equipped near the vibrating fuel rod to measure the trace of the rod motion. Four displacement sensors were attached to each spring /dimple specimen jig, which measured the actual rod behavior during the contacts.

2.3 Data Acquisition System

The normal and shear force at each spring/dimple during the contacting are measured. The actuation of the rod with an elliptical motion and the contact displacements at each spring/dimple also were measured by using displacement sensors. All measured values of the fretting parameters (i.e. contacting force, shear force, frequency, rod traces both at the actuation position and at the spring/dimple, etc.) are displayed and stored in the PC on real time basis by using LabVIEW®.

3. Results

Fig. 2 shows the fuel rod motion and the actual contacting behavior at the spring/dimple contact regions. The fuel rod was rotated in an elliptical orbit with a frequency of 30 Hz, horizontal displacement range of 500 μm and vertical displacement of 400 μm up to $2x10^{6}$ cycles in the room temperature air. A flat shape of the spring was used in this study. All the clearances between the fuel rod and springs/dimples were set to 0.1 mm. It is apparent that the fuel rod motion could be adjusted enough to simulate the vibration between the fuel rod and spring/dimple.

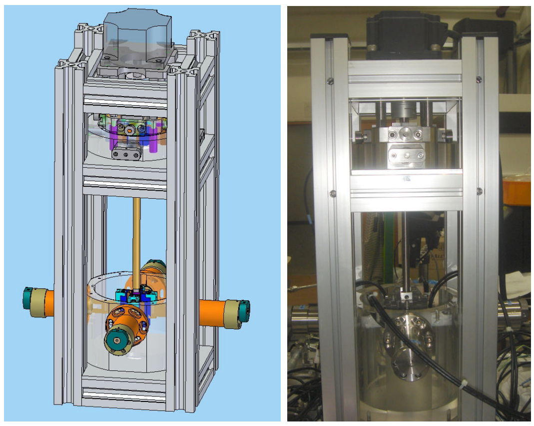


Figure 1. Schematic diagrams of the developed fretting wear test rig.

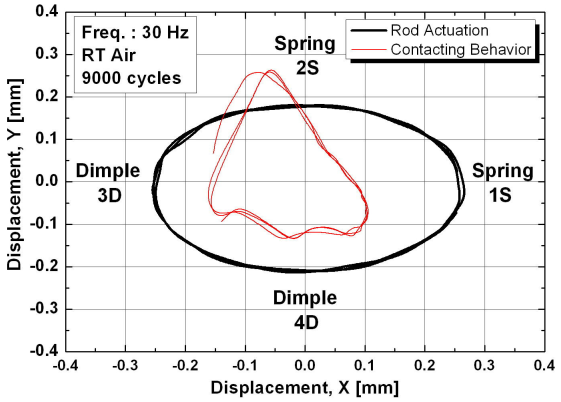
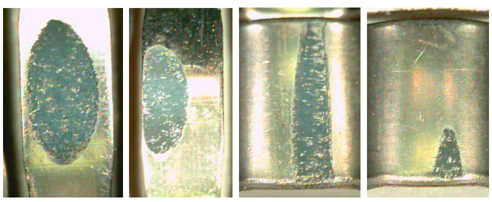


Figure 2. Variation of the contacting behavior of the fuel rod with an elliptical rod actuation in a 1x1 unit cell.

As shown in Fig. 2, it is apparent that the contacting behavior between the fuel rod and each spring/dimple was quite complex. Even though the clearance between the fuel rod and spring/dimple (i.e. 0.1 mm) is existed under an elliptical motion, the trace of the fuel rod motion against the springs and dimples used in this study is almost triangular shape. This means that the wear damage of one spring or dimple in the 1x1 unit cell is almost negligible because each vertex of triangle indicates the impacting motion. In this experiment, the 4D as denoted in Fig. 2 was expected to show the relatively small amount of the wear damage. Fig. 3 shows the OM results of the wear scar at each spring and dimple. As mentioned above, the wear scar of the 4D specimen is relatively small at the bottom dimple. Also, the wear scars of 2S and 3D are located at the left of spring and the right of dimple, each respectively. It means that the fuel rod was contacted with the 2S and 3D specimen almost simultaneously after impacting with the 1S spring. This is a good agreement with the trace of the fuel rod motion as shown in Fig. 2. So, it is possible to evaluate the contacting behavior of the fuel rod against various supporting spring/dimple shapes by using the developed fretting wear tester.



1S 2S 3D 4D

Figure 3. Result of OM observation at each spring and dimple specimen.

4. Conclusion

The developed fretting wear tester for 1x1 unit cell can be useful tools for determining the wear resistance of a developed or developing grid spring/dimple. So, it is necessary to evaluate the contacting behavior with the variation of spring/dimple shape.

ACKNOWLEDGEMENTS

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