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A Study on Abrasive Wear Behavior of Spacer Grid Materials for Nuclear-Power Plant

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1. Introduction

Spacer grid is one of the key components of a light water reactor (LWR) fuel assembly. The most important function of it is to hold the fuel rods to maintain the distance between the fuel rods inside a fuel assembly. At the reactor core in operating power plants, a fretting damage has been frequently reported between a nuclear fuel rod and its supporting spring/dimple of the fuel assemblies. This is due to a flow induced vibration (FIV), Which results from the primary coolant that rapidly passes around the fuel rod to remove the excess heat generated by the nuclear reaction. Fretting damage is generally caused by fretting wear, which includes various wear mechanisms such as an oxidative, adhesive, abrasive wear, etc., or fretting fatigue, which includes a surface or bulk fatigue. The purpose of the present work are to investigate the variation of the materials with increasing number of cycles and sliding velocity under abrasive wear test and to examine the wear mechanism at each test condition.

2. Experimental procedure

2.1. Materials and specimen

The disk specimen was prepared with the dimensions of 56mm in diameter, and 0.45mm in thickness by using a Zirconium alloy. Another disk specimen was prepared with the dimensions of 56mm in diameter, and 0.25-mm in thickness by using a Inconel alloy. And the pin specimen was prepared with the dimensions of 83mm in length, 6mm in diameter. The schematic views of the disk and pin specimen and jig are illustrated in Fig. 1. The hardness value of the pin and disk specimens are summarized in Table 1.

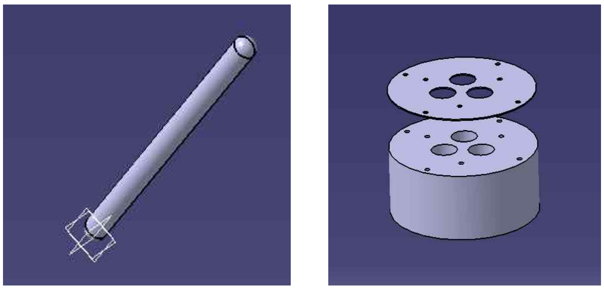


Fig. 1. Configuration of disk, pin specimen and jig
(left : pin specimen; right : disk specimen and jig)

Table 1
Vickers hardness of pin and disk specimens

Vickers hardness value		
Disk specimen		Pin specimen
Zirconium alloy	Inconel alloy	SM45C
280 ~ 300	266 ~ 272	270 ~ 275

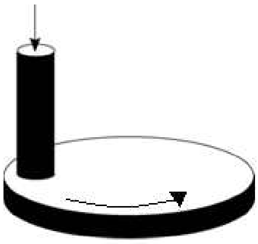


Fig. 2. Schematic sketch of a pin on disc apparatus

2.2. Testing methods

In a pin on disc test, a stationary pin is loaded axially in contact with a rotating disc, as in the schematic sketch shown in Fig. 2. The friction force on the pin can be measured, thus making it easy to compute the friction coefficient. The pin on disc machine used in these test is a Se-Jin pin on disc tester.
During each test the axial weight fixed at 9.8N. First condition performed under various sliding velocities with fixed sliding distance. The velocity between 100~500rpm are used in test. Second condition performed under various sliding distances with fixed sliding velocity. The weight of specimen before and after tests measured by electronic scale. The friction coefficient and specific wear rate extracted by each test.
Physical meaning of specific wear rate is a bulk loss of the materials which faced to random input energy.

$$\dot{\omega}_s = \frac{\Delta m}{\Delta t}\frac{1}{\upsilon\rho F_n} \qquad (1)$$

Dimension of specific wear rate is $\mathrm{mm}^3/\mathrm{N}\cdot\mathrm{m}$. In this equation Δm is the mass loss, Δt is entire test time, υ is sliding velocity, ρ is density of the specimen, F_n is the axial force.

3. Results and discussion

In Fig. 3. the specific wear rate of Zirconium alloy and Inconel alloy are slightly decreased on increasing the sliding distance. And the friction coefficient of

Zirconium alloy is increased, but Inconel alloy's friction coefficient is decreased.

In Fig. 4. the specific wear rate of Zirconium alloy and Inconel alloy are decreased on increasing the sliding velocity. Especially, the specific wear rate of Zirconium alloy when a sliding velocity under 100rpm is very bigger than other results. The friction coefficient of Zirconium alloy and Inconel alloy are decreased.

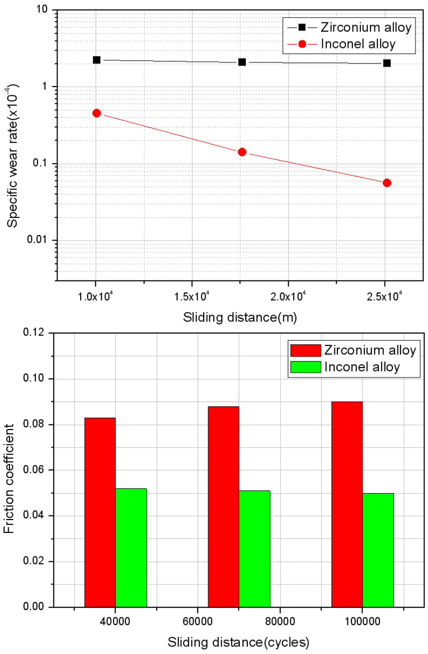


Fig. 3. Specific wear rate and friction coefficient as a function of sliding distance for materials.

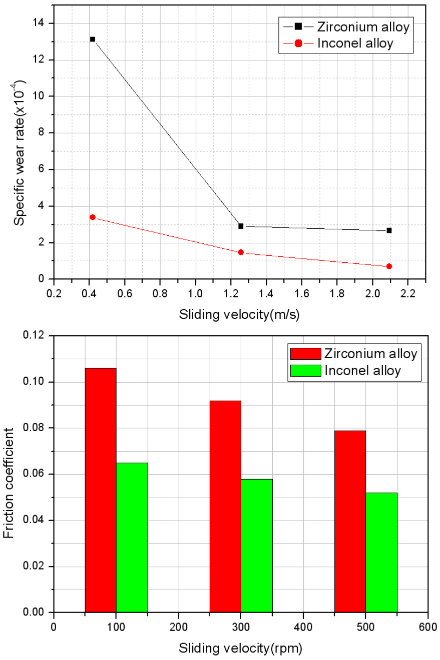
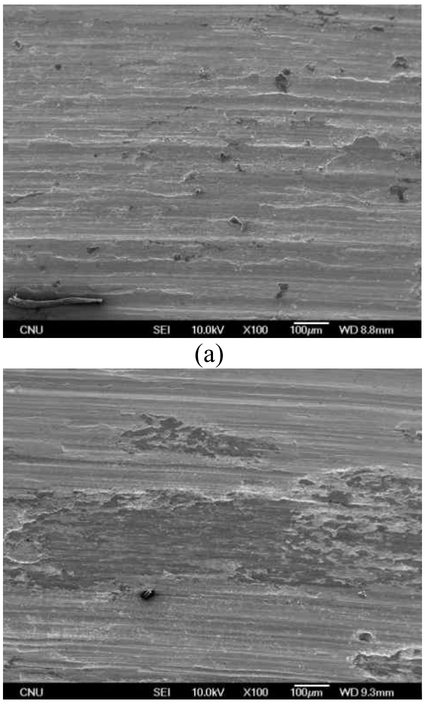


Fig. 4. Specific wear rate and friction coefficient as a function of sliding velocity for materials.

Fig. 5 is typical worn surface of the Zirconium alloy and Inconel alloy tested on a pin-on-disc apparatus at each test condition. From Fig. 5. Zirconium and Inconel alloy have different adhesive mechanism. Zirconium alloy have only SM45C particles on the worn surface. But worn surface of Inconel alloy shown surface adhesive mechanism with particle adhesive.



(a)

(b)

Fig. 5. SEM photographs of worn surface (a : Zirconium alloy, b : Inconel alloy)

4. Conclusions

In this paper, the two materials that used in spacer grid tested by pin-on-disc apparatus. The considered factors in the test are sliding velocity and sliding distance. From result data and SEM photographs, the specific wear rate of Zirconium alloy is larger than that of Inconel alloy even the hardness value of Zirconium alloy is bigger than that of Inconel alloy. This phenomenon can be explained by the difference of adhesive mechanism between two materials.

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