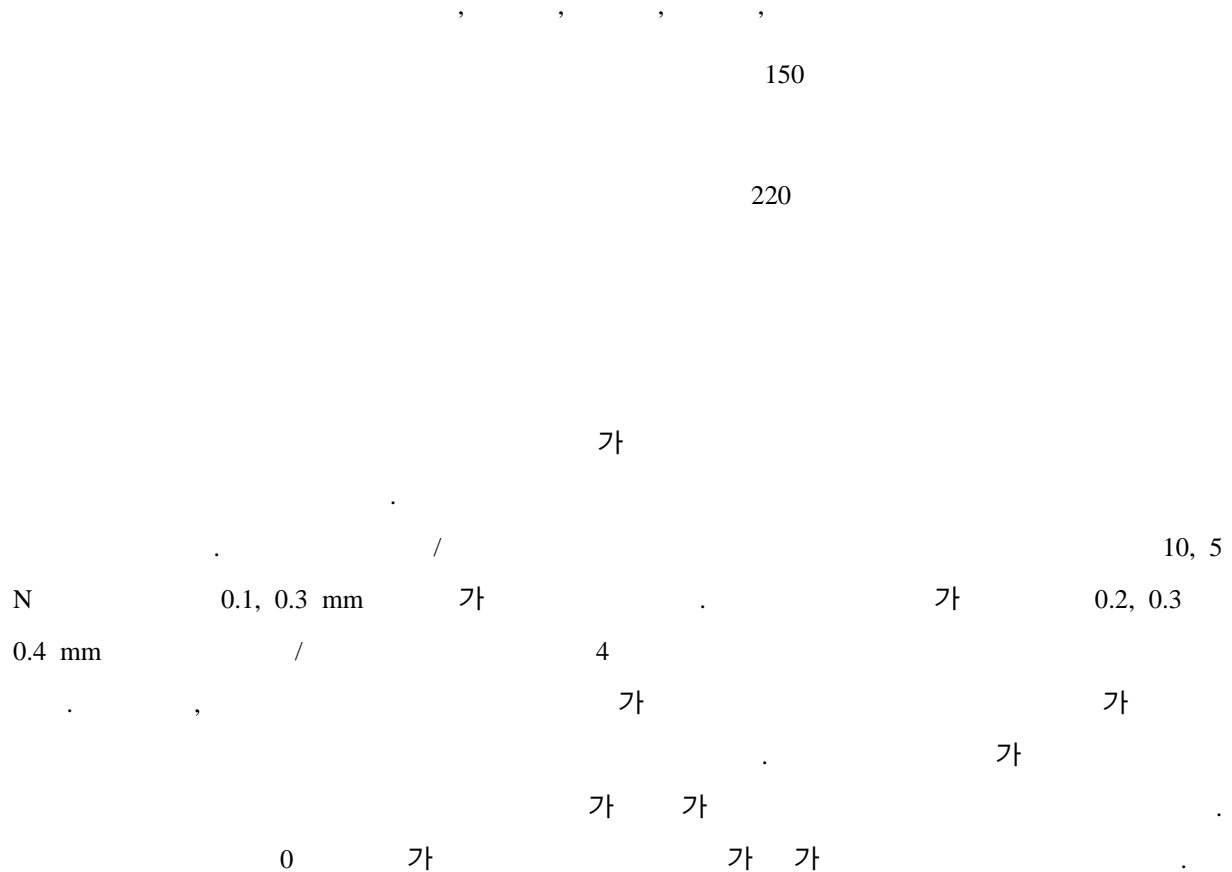


## Prediction of Slip Amplitude at the Contacts in Fuel Rod Fretting



### Abstract

Fuel rod behaviour and slip displacement are experimentally investigated for the experimental study on the fuel rod fretting that is caused by the flow-induced vibration due to the coolant flow in reactor. The experiment was conducted in air at room temperature and one span of a fuel assembly was simulated. The contact conditions were 10 and 5 N of normal load, 0.1 and 0.3 mm of gap between the spring specimen and cladding tube. The range of the vibration at the center of the fuel rod specimen was 0.2, 0.3 and 0.4 mm, and the displacement near the contact was measured with four displacement sensors. As results, the measured vibration displacement increased considerably from the contact to gap condition but almost no variation was found from the difference of the actual normal load and gap size. The slip displacement was larger when the cladding tube and spring was in contact compared with the case of gap existence. This can provide that the condition of null contact load is the most possible for the wear initiation in fuel rod fretting.

1.

0.6 mm ) 가 . ( , ) 가 가 ( ) 가 . , .

(mechanism)

가 .

가

가

1997

가

1 ~ 5

(loop)

500 ~ 1000

(Endurance Test)

가 .

1

가

가

가

가

,

가

,

.

,

/

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( )

가

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가

가

가

(

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## 2.

### 2.1

1

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가

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2

/

4

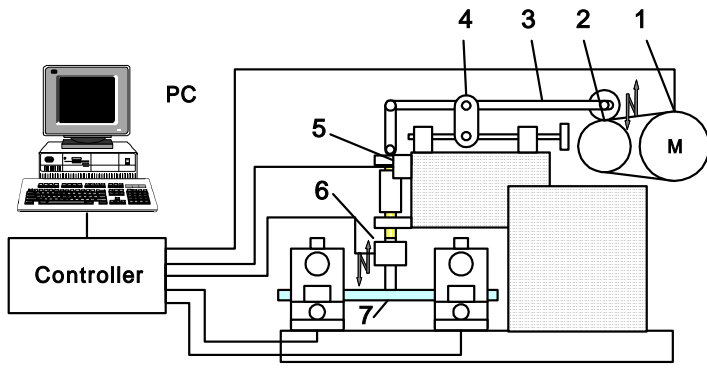
,

/

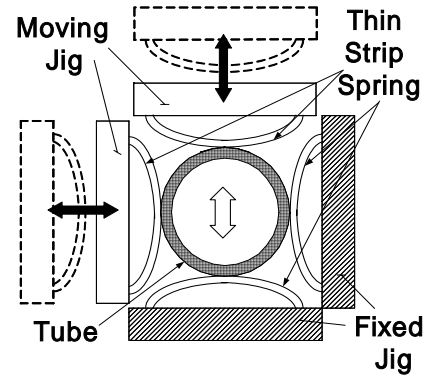
[1]

### 2.2

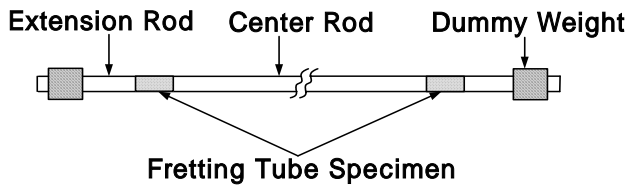
/



1. Servo-Motor, 2: Eccentric Cylinder, 3: Lever, 4: Movable Hinge, 5: LVDT, 6: Load Cell, 7: Tube Specimen.



2.



3.



4. PLUS-7

9.5 mm, 0.6 mm, 3

(span; 522mm)

55 mm

( )

( )

522 mm

(PLUS-7 )

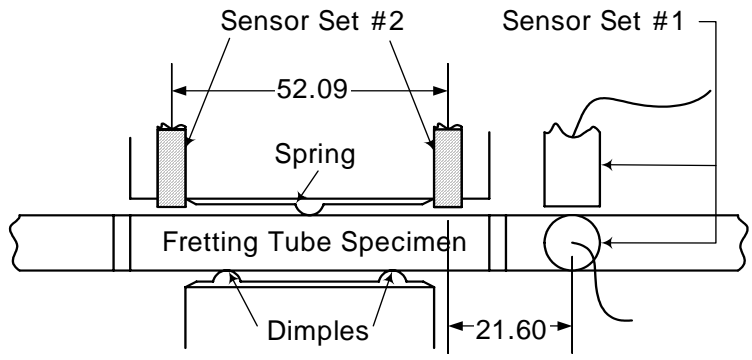
4

### 2.3

( , )  
0.2, 0.3, 0.4 mm 가  
30 Hz 가 가

( )

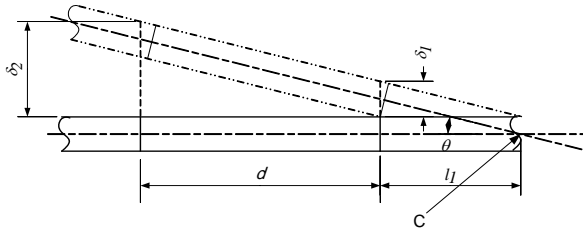
가



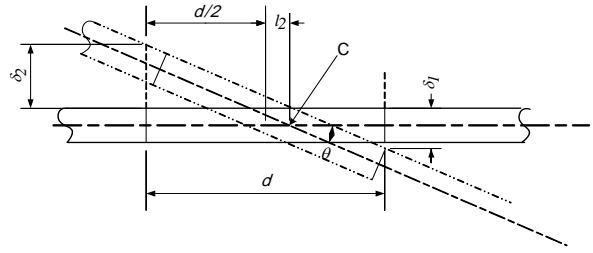
5. : Set #1 Set #2 .

(0.2, 0.3, 0.4 mm) 가 30 Hz  
 1 가 30 Hz .  
 / 10 N, 5 N  
 0.1 mm, 0.3 mm 가 가 .  
 12 가 ( 3 가 × 4 가 )가 ,  
 30 가 ( ) ( )  
 (KEYENCE EX-V Series) ,  
 가 , 가  
 , /  
 가 .

3.  
 6 가 가  
 가 가  
 가 , /  
 가  
 I II .  
 522 mm  
 52.09 mm ( , )



(a)



(b)

: (a) I (b)

II. 6.

가 .  
 , 가 /  
 가 가 .

6 d (52.09 mm) ,  $\delta_1, \delta_2$  가  
 ( ) 8  
 .  $l_1$  I ,  $l_2$   
 II (d/2) . ,  
 s .

3.1 I  
 I

가 s 6(a)

$$s = \frac{(l_1 + d/2)(1 - \cos \theta)}{\cos \theta} \quad (1)$$

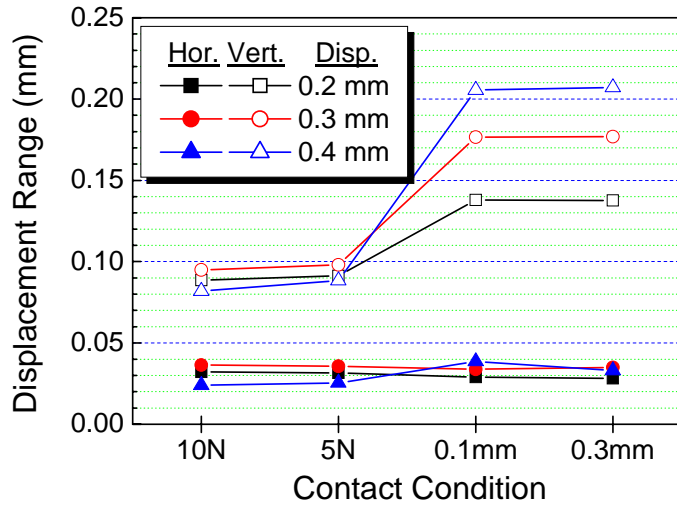
$$, l_1 = \delta_1 / \tan \theta, \theta = \tan^{-1} \left( \frac{|\delta_2 - \delta_1|}{d} \right).$$

3.2 II

$\delta_1, \delta_2$  가 ( , 가  $180^\circ$ )  
 6(b)

s .

$$s = \frac{l_2(1 - \cos \theta)}{\cos \theta} \quad (2)$$



7. 가 ( 5 sensor set #1  
; Hor.: , Vert.: , Disp.: ).

$$l_2 = \frac{d (|\delta_2| - |\delta_1|)}{2 (|\delta_2| + |\delta_1|)}, \quad \theta = \tan^{-1} \left( \frac{|\delta_1|}{d/2 - l_2} \right)$$

4.

4.1

7 가 (0.2, 0.3 0.4 mm) ( 10 N, 5 N  
0.1,0.3 mm) ( ) .  
( 5 sensor set #1)  
, 7  
가 . 가 가  
가 , /  
가 가 . ,  
가 0.2 mm 0.3 mm 가 가 0.3 mm  
0.4 mm , 가 가  
( )  
가 . 0.4 mm 가 0.2  
mm 0.3 mm 가 0.2 mm 0.3 mm 가  
0.3 mm 0.4 mm .

, 가 가 ,  
가 . ,

10 N 5 N

가

가 0.1 mm 0.3 mm

가 0.2 mm 0.3 mm /

, 0.4 mm 가 가 ,

가 , 0.4 mm

가 가 가

가 Out-of-Plane

, 0.4 mm , 가

0.4 mm

가 0.2 mm 0.3 mm

#### 4.2

3 I II /

3

( ) 8

가 가 0.4 mm

가 ,

10 N, 5 N 0.1 mm, 0.3 mm /

( 5 sensor set #2)

. 8 /

가 , 180°

가 0.2 mm, 0.3 mm

3.2 II

9 8 가

/ 9 가

/ ( ) 가 ( ) ,

가 6( )

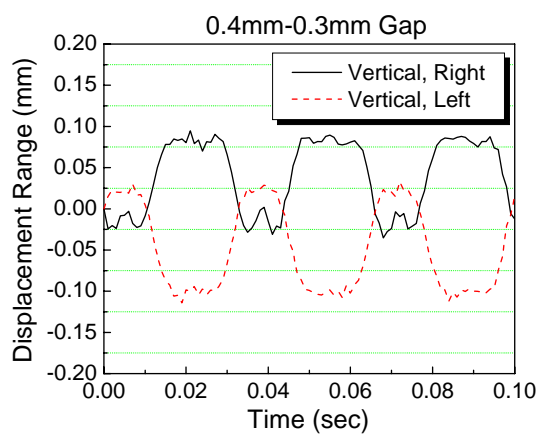
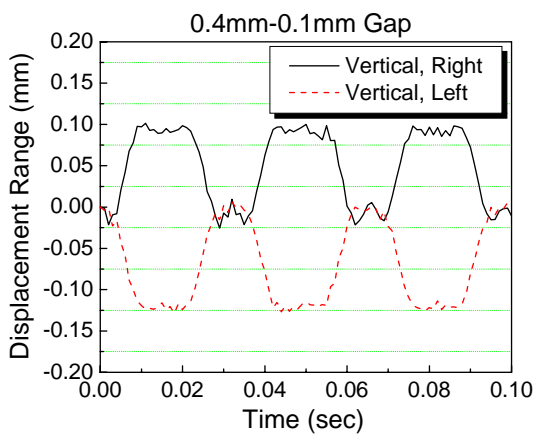
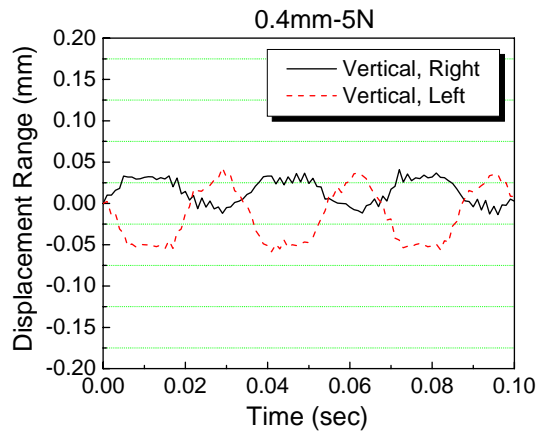
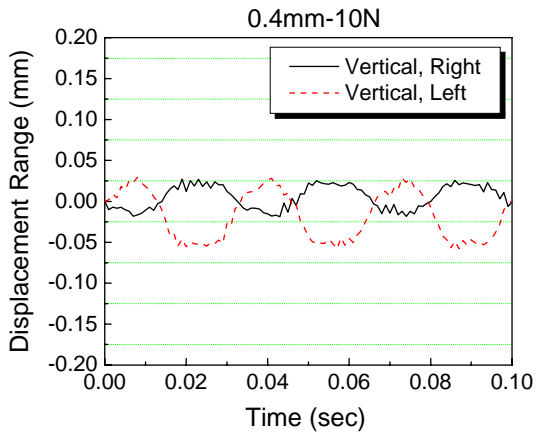
가 가

가 가 가

가 가

3  $\delta_2$   $\delta_1$  2





8.

.

가

가

1

8

가

3.2

II

가

가

가 가

가

가

가

가

가

가

/

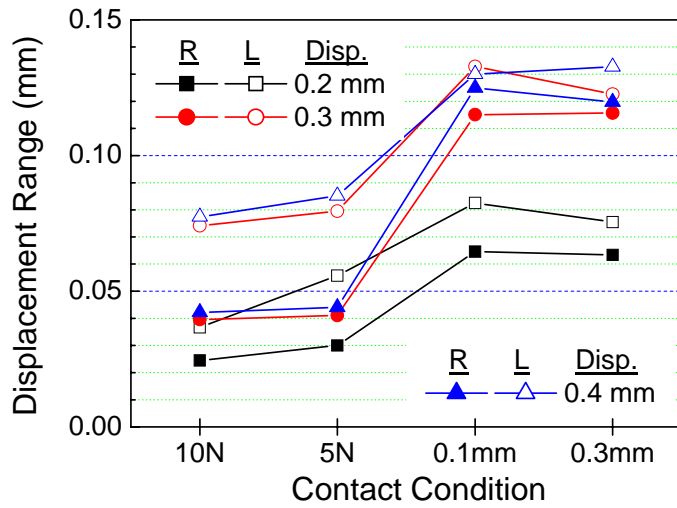
가

1

/

가 가

,



9. 가 ( 5 sensor set #2 ;  
 L: , R: , Disp.: ).

1. (μm)

Displacement at Center (mm)	Contact Condition			
	10 N	5 N	0.1 mm Gap	0.3 mm Gap
0.2	0.53	0.78	0.32	0.23
0.3	0.79	0.83	0.19	0.08
0.4	0.78	0.83	0.05	0.13

가 .  
 ,  
 가 .  
 / 가 가  
 가 .

**4.3**

9 가 가

가 .  
 가 /

[2].

가 가  
 가 가

ploughing( )

가

(wedge)

ploughing

. Ploughing

가

가

가

가

[2].

가

가

가

, ploughing

,

가

가

5.

1.

가

가

,

가

2.

가

가

가

가

ploughing

가

가

(

) ploughing

가가

1. 4 (2001) 2001 , 245-251.
2. 4 (2002) 2002 , 5 .