Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Deformation Behavior of Cell Spring of an Irradiated Spacer Grid

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1. Introduction

Mechanical properties of a space grid of a fuel assembly are of great importance for fuel operation reliability in extended fuel burnup and duration of fuel life. The spacer grid with inner and outer straps has cell spring and dimples, which are in contact with the fuel rod. The spacer grids supporting the fuel rods absorb vibration impacts due to the reactor coolant flow and also grid spring force is decreasing under irradiation [1,2]. This reduction of contact force might cause the grid-to-rod fretting wear. The fretting failure of the fuel rod is one of the significant issues recently in the nuclear industry from an economical as well as a safety concern [3,4]. Thus, it is important to understand the characteristics of cell spring behavior for an irradiated spacer grid.

In the present study, the stiffness test and dimensional measurement of cell springs were conducted to investigate the deformation behavior of cell springs of an irradiated spacer grid in a hot cell at IMEF (irradiated materials examination facility) of KAERI.

2. Methods and Results

2.1 Experimental set-up

Fig. 1 shows the schematic illustration of the cell spring test. It consists of lower grip to support the grid outer strap and upper grip with a loading rod, which imposing the compression to the cell spring designed as Fig. 2. Stainless steel with a hardness of 40 HRC and Al6061 were used for the loading rod and jig, respectively. The loading rod passes through a specified cell position along the outer strap of the grid and presses the cell spring tested. Fig. 3 shows the experimental set-up for the cell spring test with an irradiated grid in a hot cell.

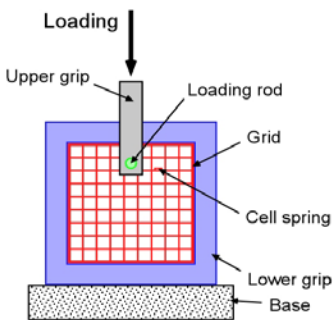

Fig. 1. Schematic diagram of grid cell spring test.

2.2 Cell spring tests of an irradiated grid

Experiments were carried out using the universal testing machine (Instron 8562) with a 1 kN load cell at room temperature. The initial load was -4 N and the constant velocity of the crosshead used was 0.5 mm/min. The load was taken off at 0.4 mm displacement. Four measurement points were selected for the cell spring stiffness test in the present study. The data acquisition system associated with the control system of the universal testing machine records the load and the displacement during a compression of a cell spring.

The load-deflection curves as shown in Fig. 4 were obtained by applying a vertical compressive load onto the cell spring. They were calculated based on the displacement corrected by the machine compliance considering the test equipment, loading rod and grips.

The deformation mechanism of the cell spring was dependent on the different measurement points. For cells of D17 and P17, the load increased linearly up to the maximum load as the deflection increased. For cells of A17 and T17, the load increased linearly at the initial loading stage and sharply increased during the compression.

2.3 Dimensional measurement of cell springs

In PWR (Pressurized light Water Reactor) fuel assemblies, the spacer grids support the fuel rods by the friction forces between the fuel rods and the springs/dimples. Under irradiation, they absorb vibration impacts due to the reactor coolant flow and also grid spring force is decreasing and rod to grid gap opening may occur. Thus a dimensional change of the grid cell vacated by removed rods was measured to investigate the irradiation effect on the characteristics of deformation behavior of cell spring depending on the positions. A grid inspected by the ccd camera is moved

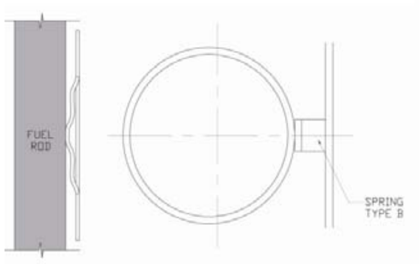

Fig. 2. Shape of the cell spring.

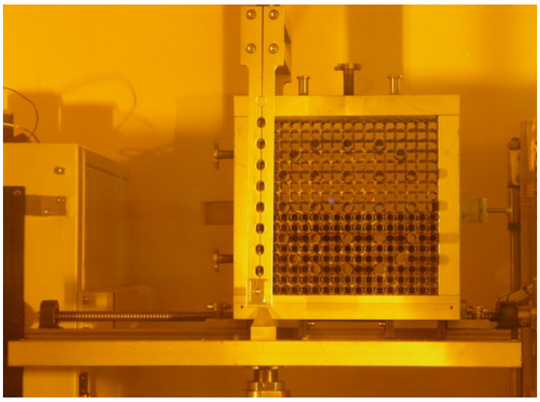

Fig. 3. Grid cell spring test in a hot cell.

using an x-y table so that the camera can take the images of the parts (such as spring and dimple) of the grid at two different positions. The displacement of the x-y table is measured using the linear scale, and then the coordinate values of it are converted to distance between two points by a dimensional measurement program. The system is calibrated by the gage blocks with 50 mm and 200 mm length before the measurement.

Fig. 5 shows the dimensional measurement of a cell spring height of the irradiated grid in a hot cell. The cell spring height listed in Table 1 can be measured as distance between a tangent of the cell spring and the outer strap.

Table 1 shows the difference of the cell spring height depending on the positions measured. The values of A17 and T17 cells were lower than those of D17 and P17 cells. Thus the phenomenon of load increment of the cell springs can be represented with the configuration of the cell spring illustrated in Fig. 2. For cells of D17 and P17, the small part of the loading rod was in contact with the cell spring during the compression. However, for cells of A17 and T17, the large part of the loading rod was in contact with the cell spring after the initial compression stage since the upper part of the cell spring could be less deformed. This contact behavior induced the rapid load increment at the certain loading stage for cells of A17 and T17.

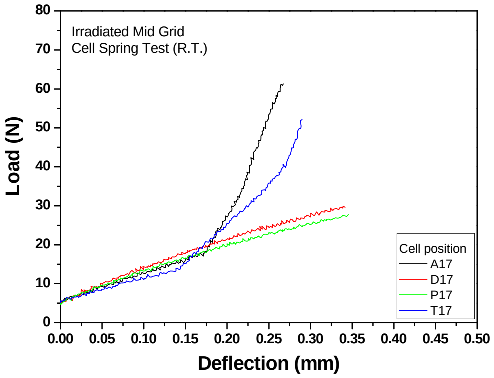

Fig. 4. Load-deflection curves of grid cell spring tests.

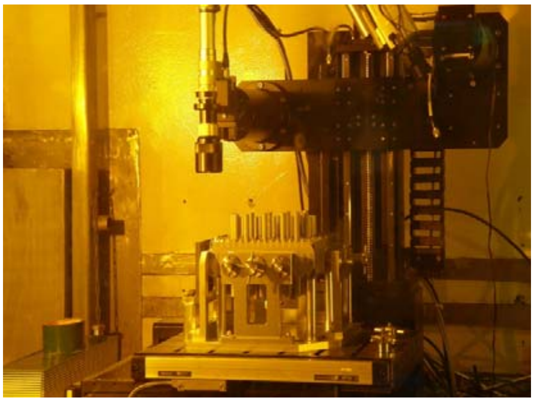

Fig. 5. Experimental set-up for the measurement of the grid in a hot cell.

Table I: Cell spring height depending on cell positions

Cell position	A17	D17	P17	T17
Height (mm)	1.01	1.08	1.12	0.95

3. Conclusions

In order to evaluate the fretting wear performance of an irradiated spacer grid, hot cell tests were carried out at IMEF of KAERI. Hot cell examinations include spring stiffness measurement and dimensional measurement for the different cell springs. The stiffness of cell springs was dependent on the measurement positions, leading to significant load variations. It was found that the change in size of cell springs due to irradiation-induced stress relaxation and creep during the fuel residency in reactor core affected the contact behavior between the loading rod and the cell spring. This was the main cause of different load increment for the cell springs during the compression of the irradiated spacer grid.

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