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A Study on Cell Size of Irradiated Spacer Grid for PWR Fuel

Y. G. Jin [a*], G. S. Kim [a], W. S. Ryu [a], S. J. Baek [a], D. S. Kim [a], S. B. Ahn [a], Y. S. Choo [a], Y. B. Chun [a], J. I. Kim [b], Y. H. Kim [b], J. J. Lee [b]
[a]*Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon 305-353, Korea*
[b]*KEPCO NF, 989 Daedeok-daero, Yuseong-gu, Daejeon 305-353, Korea*
[*]*Corresponding author: ygjin@kaeri.re.kr*

1. Introduction

The 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. A 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 grid spring force decreases under irradiation [1,2]. This reduction of contact force might cause grid-to-rod fretting wear. The fretting failure of the fuel rod is one of the recent significant issues 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 and the change in size of grid cells for an irradiated spacer grid.

In the present study, the dimensional measurement of a spacer grid was conducted to investigate the cell size of an irradiated spacer grid in a hot cell at IMEF (Irradiated Materials Examination Facility) of KAERI.

2. Experimental

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 the grid spring force decreases and a rod-to-grid gap opening may occur.

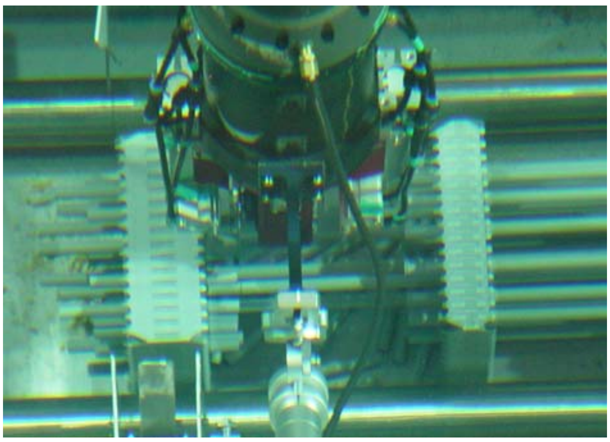

Fig. 1. Cutting machine to cut the guide and instrumentation tubes simultaneously at both sides of a grid using abrasive wheels.

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 a cell spring depending on the positions.

For the preparation of a spacer grid without any damage, an irradiated fuel assembly transferred from a nuclear power plant was dismantled and cut by the underwater cutting machine at PIEF (Post Irradiation Examination Facility) of KAERI, as shown in Fig. 1.

As the grid of a nuclear fuel bundle is irradiated by neutrons in the core of a reactor, it can be a highly radioactive substance during operation. Therefore, the examination and measurement apparatus must be designed to control it remotely from the operation area of the hot cell facility. As shown in Fig. 2, a 3-dimensional measurement apparatus consists of a measurement part, a controller part and a PC & DB system. A measurement part is installed in the M5a hot cell of IMEF through the roof door of the hot cell, and the other parts are installed in the operating area of IMEF of KAERI.

A grid inspected by a CCD camera is moved 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 its coordinate values are then converted into the distance between two points using a dimensional measurement program. The system is calibrated by gage blocks with 50 mm and 200 mm length before the measurement of the irradiated spacer grid.

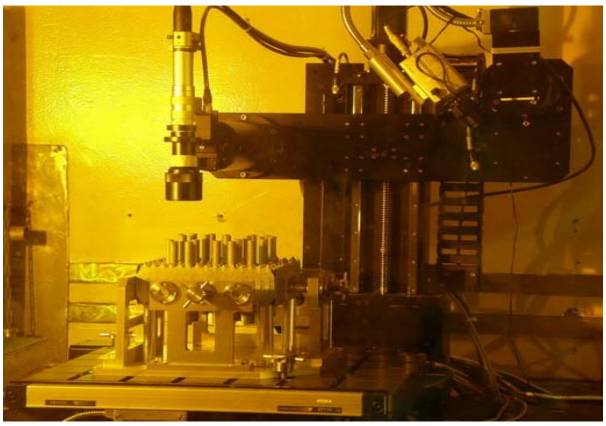

Fig. 2. Experimental set-up for the measurement of the grid in a hot cell.

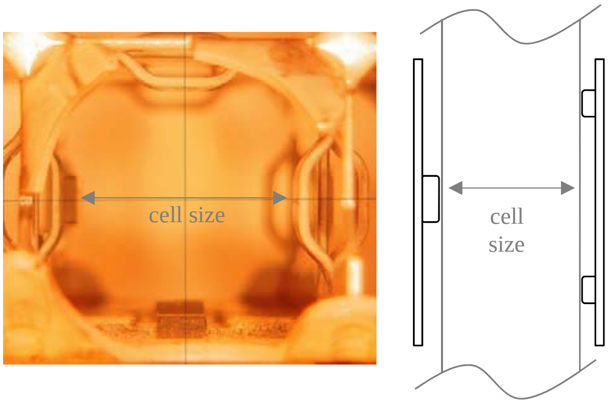

Fig. 3. Image and schematic illustration of the cell size of the spacer grid.

Fig. 2 shows the dimensional measurement of the cell size of the irradiated grid in a hot cell. The cell size can be measured as the distance between a tangent of the cell spring and the dimple horizontally and vertically, as shown in Fig. 3.

Fig. 4 shows the grid-to-rod gap which is defined as a relative value of a cell size to an initial diameter of fuel rod in the horizontal and vertical directions.

A positive value means the existence of a gap, and a negative value means the part of the fuel rod was in contact with the cell spring and dimple. The initial size of the grid cells was designed to be smaller than the rod diameter. This negative gap value keeps the spring force for grasping a fuel rod tightly [3,4].

It was found that the fuel rod was in contact with the cell spring in the horizontal direction. However, some of the grid cells have a small gap between the fuel rods and cell spring in the vertical direction. During operation, the grid cells in the vertical direction are enlarged, which induces a loss of compression of a grid spring.

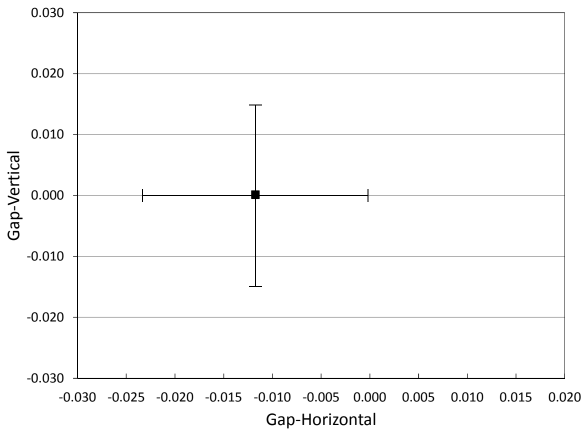

Fig. 4. Plot of the gap determined by the measurement of the grid in a hot cell.

3. Conclusions

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 dimensional measurements for the irradiated spacer grid. The change of cell sizes was dependent on the direction of the spacer grids, leading to significant gap variations. It was found that the change in size of the cell springs due to irradiation-induced stress relaxation and creep during the fuel residency in the reactor core affect the contact behavior between the fuel rod and the cell spring.

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