A study of impact characteristics of spacer grids of PWR Fuel Assembly

Joung-Yeul Lee*, Il-Kyu Kim, Jae-Jun Lee, Yong-Hwan Kim, Jung-Cheol Shin,
KEPCO Nuclear Fuel, Daejeon, 305-353, Korea
**Corresponding author : joungyeul@knfc.co.kr*

1. Introduction

Fuel assembly is a structure which normally has horizontal and vertical length of about 200 mm and height length 4,000 mm.[1] Because of this imbalance of aspect ratio, it is easy to excite horizontal vibration during seismic disturbance.

The structure of a fuel assembly consists of several elements such as fuel rods, guide thimbles, spacer grids and top and bottom nozzles. The fuel rods are supported by the springs and dimples of the grid spacer, which is a structural component for resisting the external load at an abnormal condition. If abnormal condition occurs, due to its small lateral gaps in the core, lateral impact load will occur between spacer grids and spacer grid to baffle.[2]

The characteristics of spacer grids have been changed under irradiation environment such as impact strength and stiffness by temperature, irradiation, spring relaxation, hydrogen embrittlement and others.

The purpose of this paper is to compare impact characteristics of spring relaxed spacer grid with as-built spacer grid.

2. Hot-cell Examination of the Spacer Grids

Under irradiation, grid spring force decrease and the gap opening between rod and grid may occur with spring relaxation. Spring relaxation affects impact strength and stiffness. Therefore, the cell size measurement of irradiated spacer grid was needed.

Post-Irradiation Examination of the spacer grid has been conducted at the Post-Irradiation Examination Facility of Korea Atomic Energy Research Institute. The picture and schematic of an elementary grid cell are shown in Figure 1.

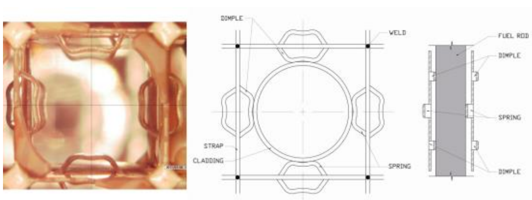


Figure 1. Picture and schematic of an elementary grid cell

In measurement results, the cell sizes of the mid-grid increased up to about 4 % as compared to the as-built data. Therefore, cell setting was performed that of target value 4% larger than as-built data.

3. Crush Test

The main purpose of the spacer grid crush test was to obtain the characteristics of spacer grid in support of safety evaluation. Therefore, two crush tests, which simulate grid to grid impact and grid to baffle impact condition, were performed which called through grid crush test and one-sided grid crush test.

3.1 Through grid crush test

The amount of through grid test specimen and the through grid crush apparatus is shown in Table 1 and Figure 2. The test was performed in similar temperature of reactor environment and the impact force is increased according to the increase of pendulum hammer angle.

Table 1. Amount of through grid test specimen

Test Specimens and Support Component	EA
As-built spacer grids	10
Cell Sizing spacer grids	10
Fuel Rod Sections	236
Guide Tube Sections	5

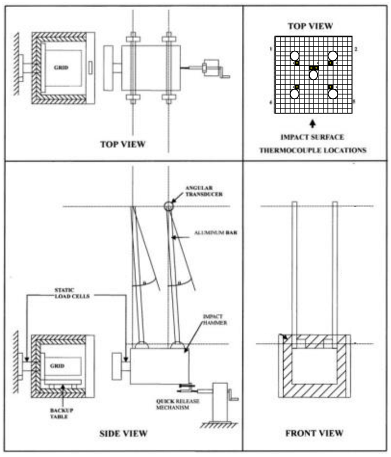
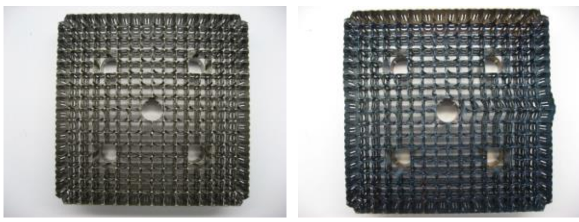


Figure 2. Through grid crush test apparatus



(a) Before test (b) After test

Figure 3. Through crush test specimens

The before and after test specimens of spacer grid are shown in Figure 3. The tests were performed using the 16X16 spacer grids made of zirconium alloys.

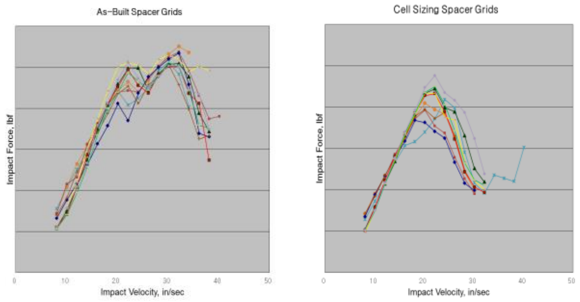


Figure 4. Results of through grid crush test

3.2 One-sided grid crush test

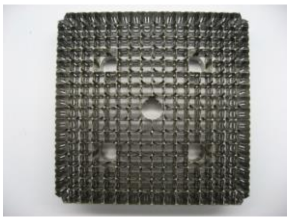
The amount of one-sided grid crush test specimen and the one-sided grid crush testing machine is shown in Table 2 and Figure 5. The test was performed in room temperature and the impact force is increased according to the increase of the height of fuel assembly section.

For testing purposes, the fuel tubes contain lead rods to simulate the weight of fuel pellets.

Table 2. Amount of one-sided grid crush test specimen

Test Specimens and Support Component	EA
As-built spacer grids	2
Cell Sizing spacer grids	2
Lead Fuel Rod Sections	236
Guide Tube Sections	5

Figure 5. One-sided grid crush test machine



(a) Before test

(b) After test

Figure 6. One-sided grid crush test specimens

The before and after test specimens of spacer grid are shown in Figure 6. The tests were performed using the 16X16 spacer grids made of zirconium alloys.

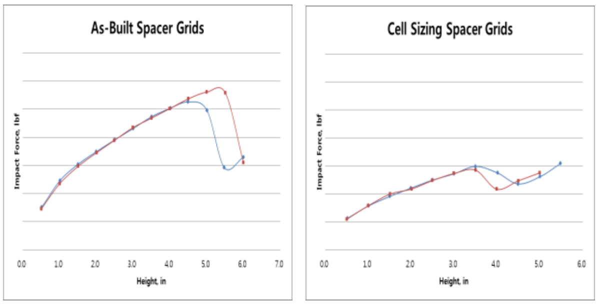


Figure 7. Results of one-sided grid crush test

4. Analysis Test Results

Figure 4 and 7 are the results of each test. The impact force of each plot is increased approximately linear with respect to the impact velocity or height until the initiation of buckling.

The dynamic test results show that the impact strength of sprig relaxed spacer grids decrease about 20% compared to the as-built spacer grids. The one-sided test results show that the impact strength of sprig relaxed spacer grid decreases about 45% compared to the as-built spacer grid. Both stiffness values were calculated using the impact duration method and its equation is shown below.

$$K = 4\pi^2 M / T^2 \qquad (1)$$

Where: T = Period of Response (sec)
K = Grid Dynamic Stiffness (lb./in)
M = Hammer Mass

The dynamic stiffness of sprig relaxed spacer grids decrease about 3% compared to the as-built spacer grids. The one-sided stiffness of sprig relaxed spacer grids decrease about 27% compared to the as-built spacer grids.

5. Conclusions

This study discussed the characteristics of spacer grid, which is affected by spring relaxation. Spring relaxation gives enormous effects to the characteristics of spacer grid. There were some differences between the dynamic crush test and the one-sided crush test such as temperature and boundary condition. However, strength and stiffness of spring relaxed spacer grid evidently decrease compare to as-built spacer grid in both tests.

To make more detailed end of life condition, hydrogen embrittlement will be performed with spring relaxed spacer grids and crush tests will be carried out.

6. References

[1] K.N, Song, Impact Analysis of the Spacer Grid Assembly for PWR Fuels.
[2] Mitsubishi Heavy Industries, Ltd, FIND: Mitsubishi PWR Fuel Assemblies Seismic Analysis Code.