Development of crush test technique for irradiated spacer grid

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1. Introduction

The spacer grid, which is used to hold the fuel rods in place and enhance heat transfer, is an important structural component in a fuel assembly. In particular, the spacer grid has a critical role in protecting the fuel assembly from external impact load under severe accident conditions, such as seismic and loss of coolant accident (LOCA). Thus, it is essential to investigate the structural integrity of irradiated spacer grid, and the evaluated data should be applied to a robust spacer grid design. The crush behavior of un-irradiated spacer grid has been extensively studied [1,2], while research on irradiated spacer grid has not yet been performed. Therefore, the purposes of this study are to develop the crush test technique and produce crush characteristics data for an irradiated spacer grid under lateral impact load.

2. Development of crush test system

A crush test system for the irradiated spacer grid was developed, as shown in Fig. 1, which was composed of five major components, including the main frame, power unit with impact hammer, heating furnace, specimen loading part, and control software.

The crush test is accomplished through the pendulum movement of the impact hammer. The power unit, which is the assembly of a servomotor and a pneumatic cylinder, rotates the impact hammer directly to the test angle, and then the impact hammer is released by the operation of the cylinder.

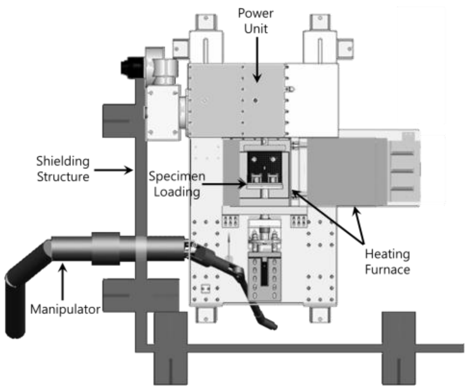

Fig. 1. Schematic of crush test system for irradiated spacer grid

The heating furnace consists of a fixed part with a heater module, and a sliding door that is opened and shuts automatically by a pneumatic actuator, which keep the specimen within the test temperature of ±5 ℃. In order to minimize heat loss from the specimen during the crush test, the confined space is opened only for the access of the impact hammer.

The specimen loading part was designed considering the convenience and stability of setting up the irradiated specimen, which could place a specimen on the test position automatically, as well as keep a tight grip on a specimen during the impact test (Fig. 2).

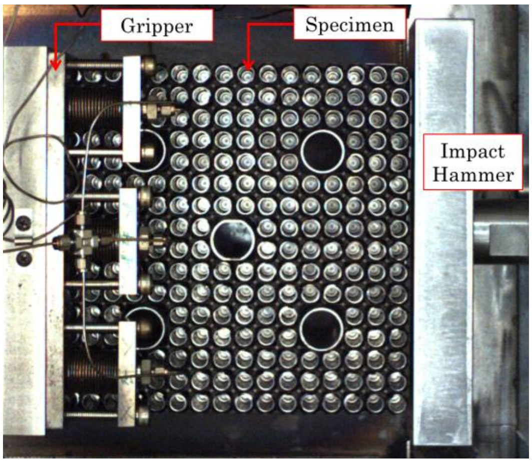

Fig. 2. Setting up of spacer grid for crush test

The shielding structures were also adequately installed to protect the tester and minimize exposure to the radiation of the irradiated spacer grid. A pure lead block with a 50 mm thickness was used as a component of the shielding structures. In addition, in order to handle the irradiated specimen remotely, the manipulator was installed on the shielding structures.

The crush test system developed in this study produces various crush characteristics data, such as the crush strength and the buckling mode, according to the following test procedures: The spacer grid, fixed rigidly by the gripper, is heated to the test temperature in the heating furnace, and then the impact hammer, set at the initial test angle, causes an impact on the side of the spacer grid. This procedure is repeated, and the hammer angle is increased by 1° at each step until specimen buckling occurred.

3. Experiment

The performance tests were carried out using two un-irradiated PLUS7 mid-spacer grids, and the crush characteristics data were successfully obtained. In order to simulate the structural conditions of the actual spacer grid assembly, claddings and guide tubes were inserted into each position of the specimen. The test temperature and initial test angle were 320±5 ℃ and 6 °, respectively, and the weight of the impact hammer was approximately 66 kg, which corresponded to the weight of one span of PLUS7 fuel assembly.

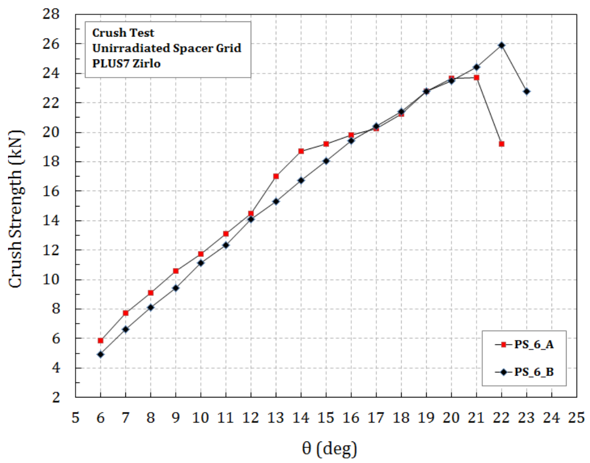

Fig. 3. Crush test results of un-irradiated PLUS7 mid spacer grid

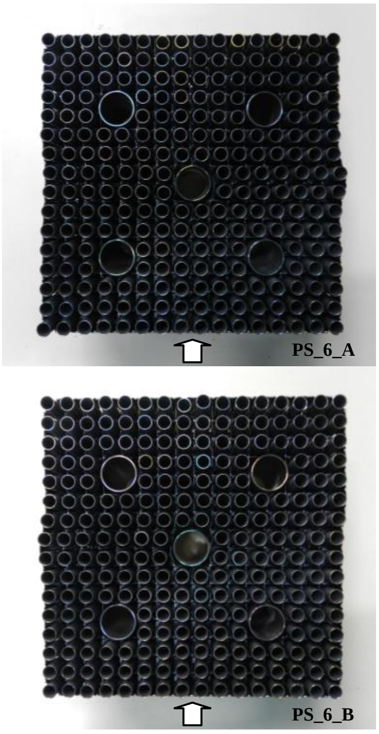

Fig. 4. Buckling mode shapes of un-irradiated PLUS7 mid-spacer grid by lateral impact load

Fig. 3 shows the results of the crush test. As the impact angle was increased, the crush strength increased approximately linear until the specimen buckled. The critical crush strength values were 23.7 kN and 25.9 kN. These differences were due to welding conditions, thickness of grid straps, and spring force [3]. The buckling mode shapes of the specimens are shown in Fig. 4. This figure demonstrates that all the specimens buckled in the middle of the specimen, where the guide tube was placed. Thus, it is assumed that the layers that have large spaces for the insertion of guide tubes are areas of high vulnerability to lateral impact load, and they may be where local buckling mainly occurs.

4. Conclusions

The performance test for the un-irradiated spacer grid was conducted using the developed crush test system. A crush test for the irradiated spacer grid will be performed, and its data will be utilized for building the irradiation behavior database as well as for an evaluation of the structural integrity of the spacer grid.

REFERENCES

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