Development of crush test system for irradiated spacer grid

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ABSTRACT

The spacer grid is an important structural component in a fuel assembly, which is used to hold the fuel rods in place and enhance the heat transfer. In particular, the spacer grid has a critical role in protecting the fuel assembly from external impact load under severe accident conditions. Thus, it is essential to investigate the structural integrity of an irradiated spacer grid and the evaluated data should be applied to a robust spacer grid design. In this paper, the crush test system for the irradiated spacer grid is presented. The crush test system was newly developed to produce crush characteristic data of the irradiated spacer grid and installed in hot laboratory at KAERI's post irradiation examination facility. The crush test system was composed of five major components: the main frame, power unit with an impact hammer, heating furnace, specimen loading part, and control software. The shielding structures were adequately installed to protect the tester and minimize exposure to the radiation of the irradiated spacer grid. The test procedure for an irradiated spacer grid was properly established, and the performance test of the developed system was successfully carried out using an un-irradiated spacer grid.

1. INTRODUCTION

The spacer grid, which is used to hold the fuel rods in place and enhance the 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. Thus, it is essential to investigate the structural integrity of an irradiated spacer grid, and the evaluated data should be applied to a robust spacer grid design. The dynamic buckling behavior of un-irradiated spacer grid has been extensively studied [1,2], while research on an irradiated spacer grid has not yet been performed. Therefore, the purposes of this study are to develop the crush test technique and produce buckling 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 Figure 1, which was composed of five major components, including the main frame, power unit with an impact hammer, heating furnace, specimen loading part, and control software. The crush test is accomplished through the pendulum movement of the impact hammer.

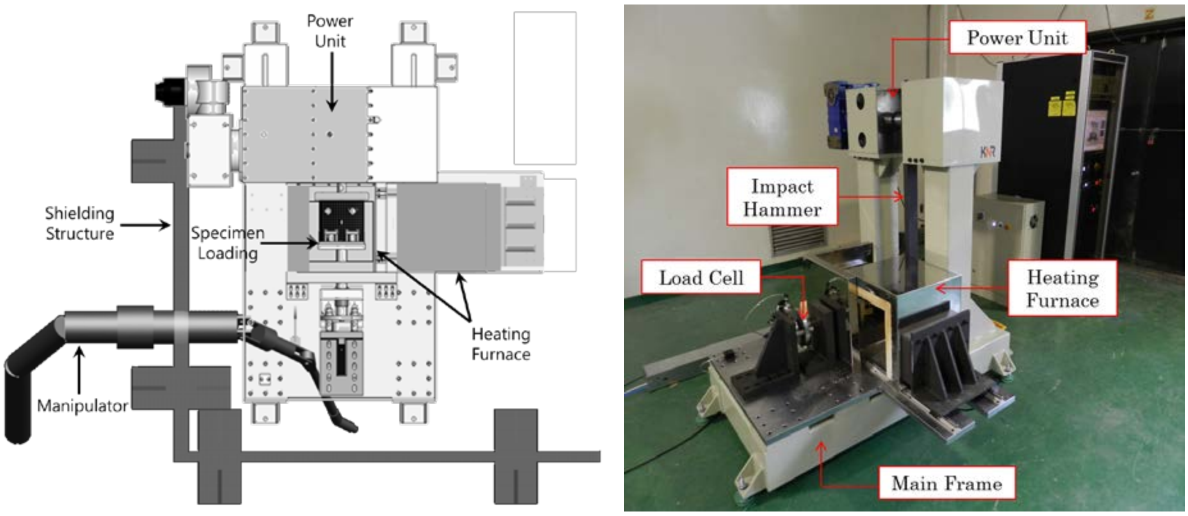

Fig.1. Schematic diagram and image of crush test system for irradiated spacer grid

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. 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 the heat loss from the specimen during the impact 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 (Figure 2).

The shielding structures were also adequately installed to protect the tester and minimize exposure to the radiation of the irradiated spacer grid, as shown in Figure 3. 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 buckling characteristics data, such as the impact 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.

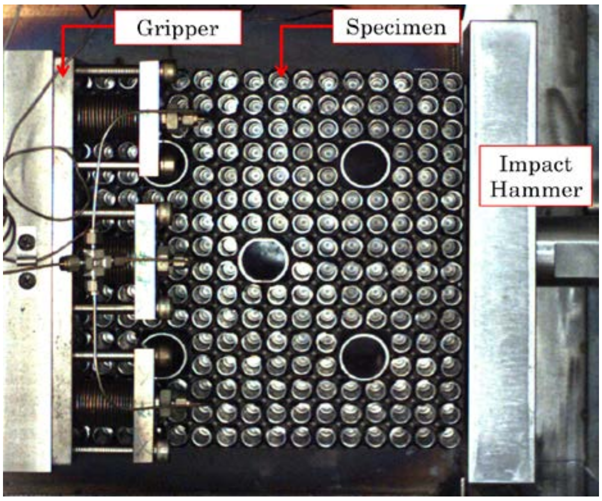

Fig.2. Setting up of spacer grid for crush test

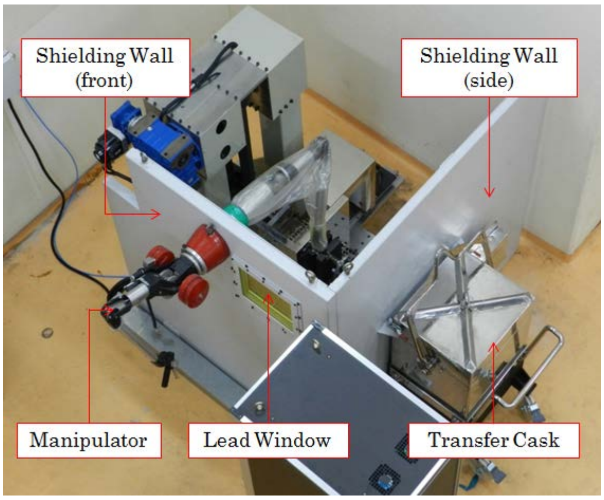

Fig.3. Shielding structures of crush test system

3. PERFORMANCE TEST OF CRUSH TEST SYSTEM

The performance tests were carried out using two un-irradiated advanced spacer grids (PLUS7), and data on the buckling characteristics were obtained successfully. 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 (Figure 4). 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. Figure 5 shows the results of the crush test. As the impact angle was increased, the impact force increased approximately linear until the specimen buckled. The critical impact force values were 23.7 kN and 25.9 kN. These differences were due to the welding conditions, thickness of grid straps, and spring force [3].

The buckling mode shapes of the specimens are shown in Figure 6. This figure demonstrates that all of 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.

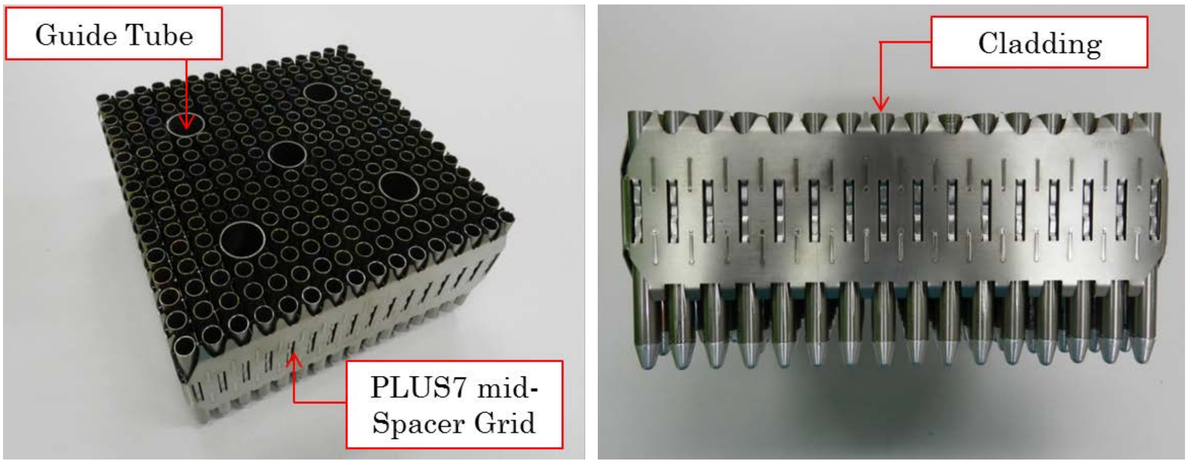

Fig.4. Un-irradiated PLUS7 spacer grid for performance test

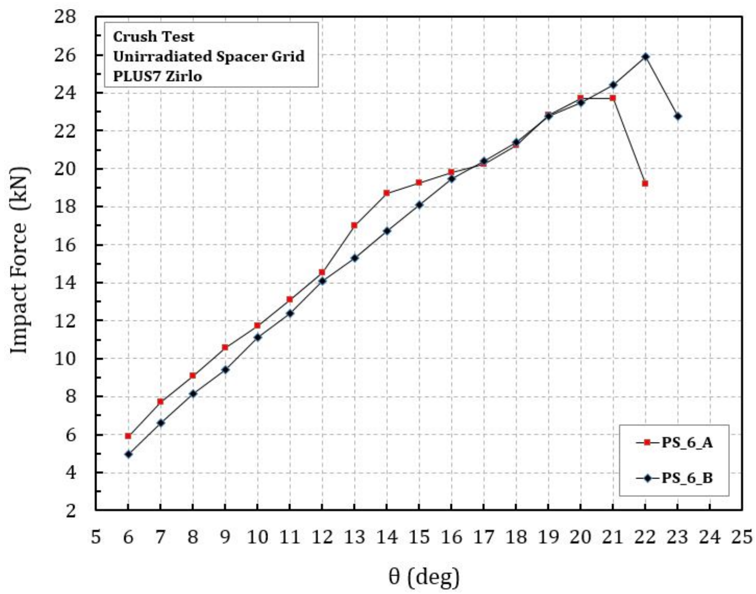

Fig.5. Test results of un-irradiated PLUS7 mid spacer grid

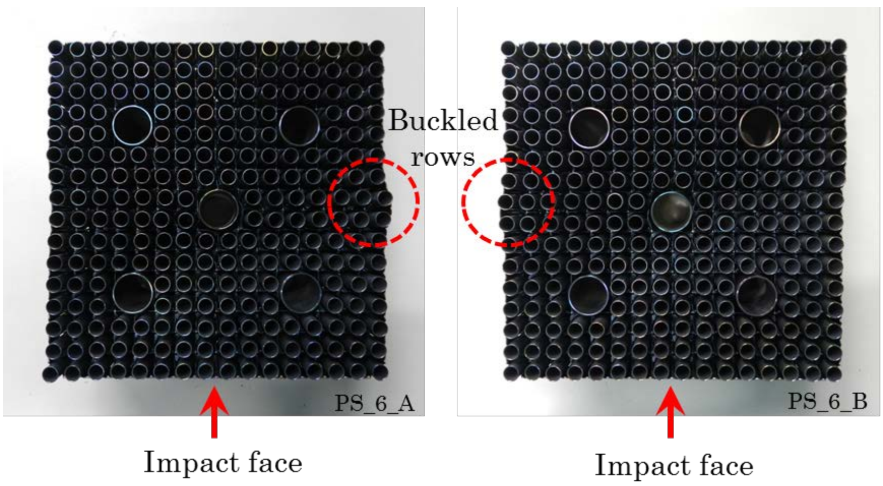

Fig.6. Buckling mode shapes of un-irradiated PLUS7 mid-spacer grid by lateral impact load

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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