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Spacer Grid Crush Scoping Tests Using the Upgraded Test Equipment

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1. Introduction

The spacer grids maintain the fuel rod pitch by providing lateral restraint and the fuel rods are restrained from axial motion by the frictional forces developed by the spacer grid springs. In addition, spacer grids should retain geometry for adequate flow channels to permit removal of residual heat and for control rod insertion to minimize the extent of fuel damage even after postulated accidents such as seismic & LOCA event[1].

In the meanwhile, these kinds of postulated accidents are evaluated through computer simulation using extensive component-wise tests and finite element analyses. Spacer grid dynamic crush value of statistical 95% confidence level on the true mean at elevated temperature should be greater than the fuel assembly impact force from computer simulation of the reactor core for seismic & LOCA event

Spacer grid dynamic impact tests are performed with the insertion of fuel rod sections and guide tube/instrument tube sections in the spacer grid cells at temperature of 600 °F to simulate the condition of fuel assembly in reactor. Until now, the tests for spacer grid crush value are depending on the overseas' equipment whenever the spacer grid design is changed or developed because the equipment is not universal but specific for spacer grid.

A series of scoping tests for spacer grid dynamic crush performance at the elevated temperature was performed using upgraded test equipment, which is being supplemented for selecting candidates of new spacer grid design having high performance and for evaluating the crush performance of commercial production spacer grids in case of design change or manufacturing process change, etc. The test results have been compared with those using overseas' equipment. The differences between two test systems are within an acceptable range.

2. Preparation of Test

Spacer grid dynamic crush test equipment consists of the testing part and the data control/acquisition part shown in Fig. 1. A testing part consists of structural frame, hammer and furnace, etc. The weight of a hammer was adjusted to fit the fuel assembly span weight. The grid cell positions of a test grid were filled with fuel tube sections and guide tube/instrument tube sections using the fixtures shown in Fig. 2. The six thermocouples were installed to measure or control the temperature: one is for controlling the temperature of test specimen in the furnace and the other five which were installed within the test specimen evenly are for monitoring the temperatures within the spacer grid. Fig. 3 shows a grid specimen installed on the back plate in a furnace and six thermocouples within a test grid. Two load cells were installed to measure impact force: one is between the hammer and the impact plate, and the other is behind the back plate installing a testing grid. A heater was installed to generate heat in the furnace, and a fan was installed to send heat from the furnace to the top of the specimen and to minimize the temperature variation in the grid specimen. A rotary variable differential transformer (RVDT) was installed to monitor the rotation of the impact bar.

Fig.1. Layout for Spacer Grid Crush Test Equipment

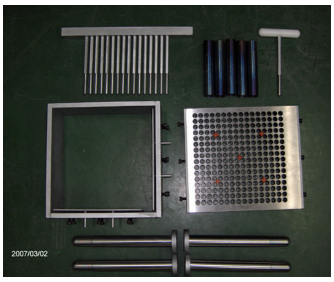


Fig.2. Fixtures for loading/unloading fuel tube sections

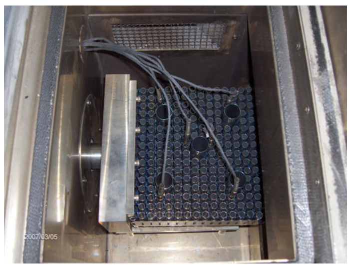


Fig.3. A Grid Specimen on the Back Plate and Six Thermocouples within the Grid Specimen

3. Grid Impact Performance Test

When the five thermocouples inserted within the test grid read the allowable elevated temperature, a hammer which is released by electromagnet hit the spacer grid specimen at elevated temperature with being opened the furnace door operated by air cylinder. Fig. 4 shows a picture just before impacting a grid specimen with the furnace door opened. An impact hammer rebounds back after impacting a specimen to hit the specimen again. To protect the second impact, the pendulum bar should be held before the second hit after recording the maximum rebound angle. The relationship between the rebound angle and the initial angle gives the coefficient of restitution. The impact forces are recorded from two load cells which attached on behind the impact hammer and behind the back beam. Impact test was performed at a starting angle of seven degree and continued until an angle to get the maximum impact force. Three specimens were impacted for this scoping test using the same procedure.

Fig.4. A Picture before Impact with a Furnace Door Being Opened

4. Test Results and Discussion

Three spacer grid specimens for comparison were impacted with fuel rod sections and guide tube/instrument tube sections being inserted in the cells.

Fig. 5 shows relative impact forces with respect to impact velocity as a result of the impact test on three grid specimens at the elevated temperature. Even though the impact forces were not increased linearly with respect to the impact velocity, the trend is almost similar at three specimens until the buckling begins. It is judged that this nonlinearity is due to the differences of transferred forces at different angle. This phenomenon is specific to the grid design used the test and reference 2 explains the similar phenomenon.

The average dynamic crush strength and the lower 95% confidence on the true mean gave 4.5% and 2% higher than those in reference 2 with the same specimens, respectively. This difference is judged within the acceptable range for the grid impact test.

The typical mode of failure for grid specimens shows a buckling at the center row including instrument tube as shown in Fig. 6.

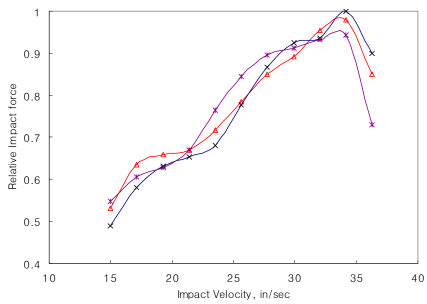
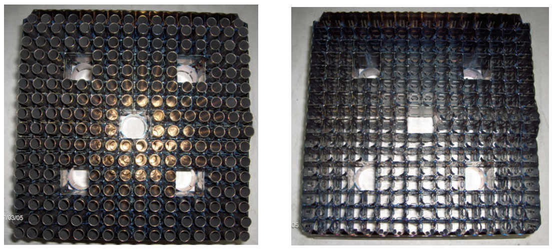


Fig. 5. Relative Grid Impact Force vs. Impact Velocity at Elevated Temperature



(a) fuel tube sections are being inserted in the cells

(b)After fuel tube sections are being removed

Fig. 6 . Typical Failure Modes on Spacer Grid Specimen

5. Conclusion

The grid impact scoping tests on three spacer grid specimens has been performed using the upgraded grid crush test equipment. The test results show good consistency with those performed using an overseas' test equipment. It is judged that this test equipment can be used for evaluating crush strength and selecting candidates of the high performance spacer grids during fuel development after evaluating the test results further in detail.

ACKNOWLEDGEMENT

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[1] NUREG-0800, "Standard Review Plan Section 4.2, Fuel System Design, U.S. Nuclear Regulatory Commission, 1996.

[2] J. M. Suh, "16x16 KAFD Mid Grid Crush Test Report," KNFC/Westinghouse Proprietary Information, 2001.