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Simulation of Spacer Grid Spring to Identify Load-Deflection Characteristics

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1. Introduction

Fuel assembly is composed of fuel rods, spacer grids, top nozzle and bottom nozzle. Of these, spacer grid supports fuel rods, maintains structural integrity, mixes coolant and filters debris [1]. To support fuel rods accurately, it needs proper load-deflection (L-D) characteristic.

L-D characteristic is the relation between displacement of spring and reaction force. L-D characteristic could be obtained by test, but it requires lots of time to perform the test. Spacer grid L-D test was performed with INSTRON test machine in KNF, and we want to obtain similar L-D characteristic by FEA (Finite Element Analysis). To predict reliable L-D characteristic of spacer grids by analysis, comparative study on the test result and analysis result should be done.

In this study, L-D analysis were performed for a spacer grid of fuel assembly, and the results were compared with the test results.

2. Test and Analysis

2.1 Spacer Grid Design

Grid used in this study is a PWR fuel zirconium grid. Each cell of the grid is composed of one spring and two dimples as shown in Fig. 1. The spring is a canoe-shaped spring which contact rod with flat surface. Fuel rods, guide tubes and an instrument tube are inserted to each cell of grid.

2.2 Load-Deflection Test

L-D test was performed at springs of spacer grid with INSTRON testing machine as shown in Fig. 2. Fuel rods were inserted at each cell which will not be used for the test, and grid was fixed in testing machine. Then springs of test cell were loaded and unloaded with a rectangular test bar. L-D data from each test cell were measured by load cell. From the data, L-D curve was drawn as shown in Fig.3.

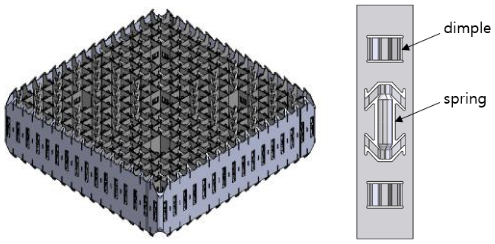

Fig. 1. Assembly and One Cell Design of Spacer Grid

Fig. 2. INSTRON Testing Machine with Grid

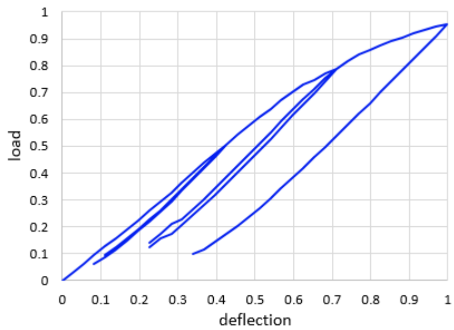

Fig. 3. Test Result. L-D Curve. Non-dimensionalized.

2.3 Load-Deflection Analysis

The spacer grid cell L-D analysis was simulated with ANSYS Workbench 15.0. Material properties of the grid and rod were defined. As it was not the whole body of the grid but the one cell, boundary conditions reflecting the design had to be provided. Welded points were fixed and continuing parts of the grid were given symmetric condition. Smaller meshes were applied at contact areas. Analysis was carried out for 2 step; step 1 was loading and step 2 was unloading. After the analysis was run, the simulation result came out. From the result, load-deflection curve was drawn as shown in Fig. 5 to be compared with L-D test result.

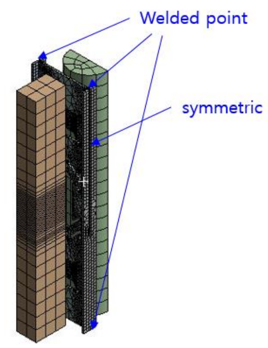

Fig. 4. 3-D Grid Model for Analysis

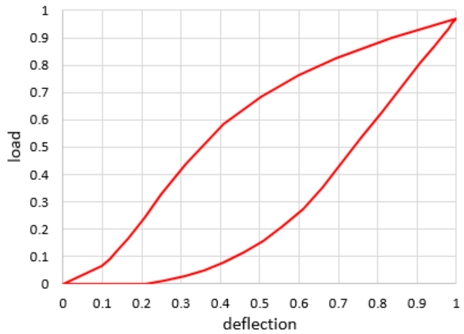

Fig. 5. Simulation Result. L-D Curve. Non-dimensionalized.

2.4 Result Comparison

Both the test result and the simulation result are drawn in Fig. 6. In the graph, all results are non-dimensionalized, and blue line is the test result and red line is the analysis result. Both results show similar load-deflection characteristic in the high deflection section, but the stiffness of simulation result is about 42 percent higher in the low deflection section than the test result. It might be caused by several reasons. First, simplified analysis model might show different characteristics from the whole grid test. Also, the boundary conditions to reflect the whole grid motion might have influence on the result. Finally, test was performed with 3 steps increasing deflection while analysis was performed with one step. These reasons might result in the gap between the test and the analysis result.

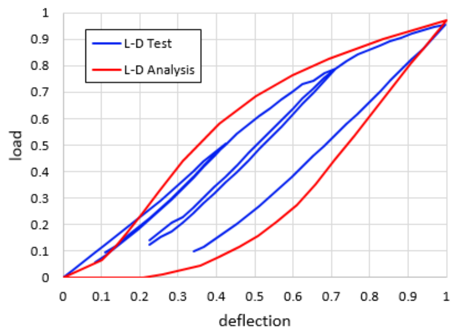

Fig. 6. Test Result and Simulation Result. L-D Curve.

2.5 Test Bar Type Validation

On the L-D test, a rectangular bar was used for loading and unloading. In real condition, fuel rod rather than rectangular bar is inserted in the grid. To justify the test result, L-D analysis was performed using rectangular bar and round bar. As shown in Fig. 7, there is almost no difference between the two results. So L-D test results performed with rectangular bar are reasonable.

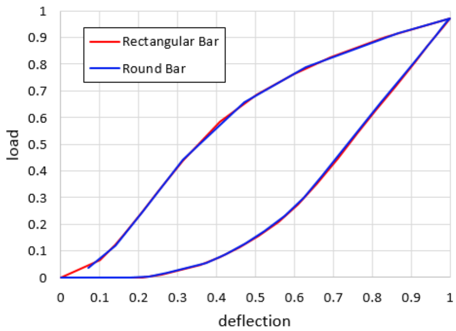

Fig. 7. Simulation Results, L-D Curve by Bar Type

3. Conclusions

In this study, the L-D characteristics of spacer grid springs were analyzed. L-D analysis was performed with one cell simplified model of the grid. The analysis result was compared with the test result. The result shows 42 percent difference in low deflection section and similar output in high deflection section. The simplified analysis model, specified boundary condition and different process between the test and simulation might be the reason of the difference.

In the future work, the analysis input parameters and conditions will be improved and also the dimple of spacer grid will be analyzed by using the spring analysis input parameters. After the analysis of dimple, more precise prediction of L-D characteristic of grid might be possible. It will be useful for predicting L-D characteristic of another spacer grid spring designs that will be developed, and it will save time and cost for the L-D test.

REFERENCES

[1] Nuclear Fuel Mechanical Design Manual, KEPCO NF