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Development of Finite Element Model for the Static Buckling Behavior of the Spacer Grid

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1. Introduction

The spacer grid is one of the main structural components of the nuclear fuel assembly. The spacer grids support and align the fuel rod. In addition they maintain the lateral spacing between the rods under operational and the accident loading conditions, such as seismic and LOCA[1-4]. Thus, the spacer grid is required to have a sufficient buckling strength to perform these functions.

In this study, finite element model was proposed to evaluate the buckling characteristics and structural behavior of partial spacer grids. A two-dimensional model was developed to simplify a real spacer gird model and save analysis time. And it was validated for comparison with experimental tests. A non-linear analysis method was introduced to perform realistic simulation. Later, the buckling analysis of the full size grid will be performed based on the analysis results of partial spacer grids.

2. Method and Results

2.1 Test specimen and procedure

The static compression tests were performed for the small size grids having different number of rows and columns (1x1, 3x3). The configuration of test setup and 1x1 specimen are shown in Fig. 1. The compression rate was controlled by the displacement of 0.05 in/min. A mechanical test is performed on an INSTRON^{TM} load frame with a maximum force of 50kN. The compressive loads acting on the grids were measured as a function of deflection during the buckling test.

2.2 Modeling of partial spacer grids

The commercial code, ANSYS 14.5, was used for the finite element analysis[5]. A two-dimensional 1x1 cell was constructed by using beam188 element. Additionally, one rod, spring and dimple were modeled by using beam188 and contact12 elements. Four contact12 elements were used to produce the correct behavior of dimple and spring. Finally, contac172 and targe169 elements were used to represent the contact behavior between the rod and strap during large deformation, and the static friction coefficient, μ, was applied between the contact elements. For the boundary conditions, specified displacement was applied on specific location, as can be seen in the scheme in Fig. 2. In other words, the bottom strap was restrained on all degree of freedom and forced displacement was applied by some displacement on the top strap in the compressive direction.

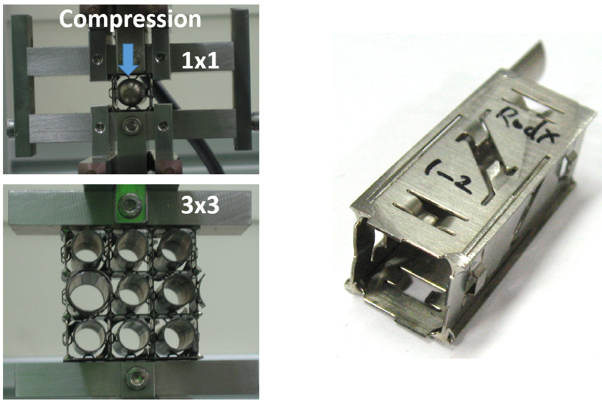


Fig. 1. Configuration of test setup and 1x1 cell's geometry

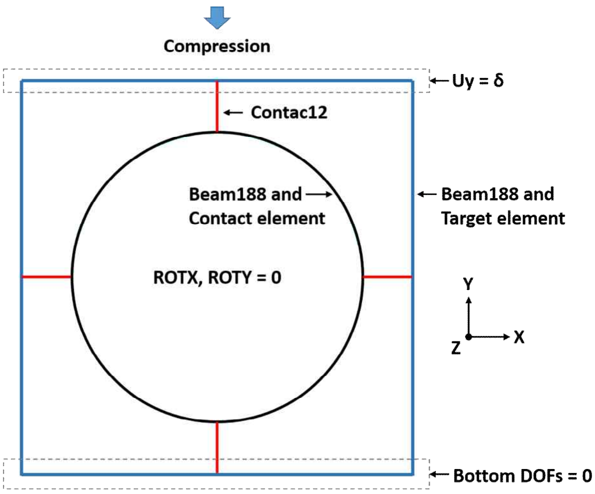


Fig. 2. Spacer grid FE model

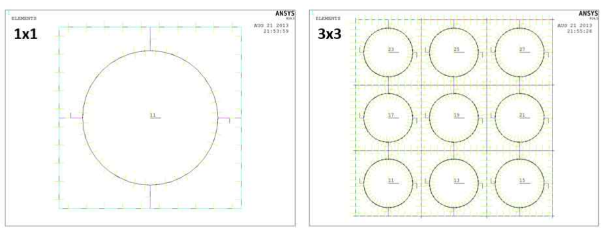
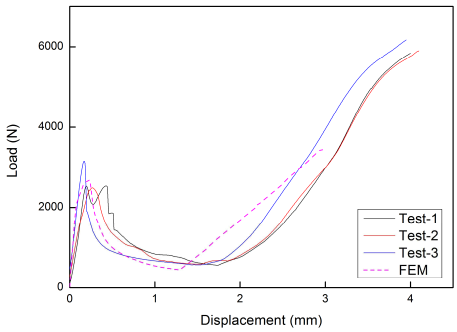


Fig. 3. 2D finite element modeling of partial spacer grid

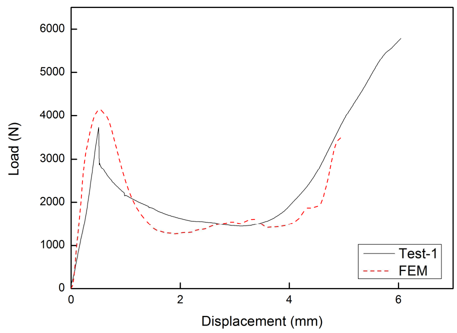
The FE models of partial spacer grid of 1x1 and 3x3 are shown in Fig. 3. The same boundary and contact conditions as the 1x1 cell were applied for the other cell. These grids were simulated statically and, as a result, the sum of nodal reaction forces and total deformation were obtained.

2.3 Comparison of FEM results with test

Fig. 4 is the comparison of the experimental and FEM results for the load-displacement. The curve based on the FE model describes the compressive behavior such as buckling strength and post-buckling behavior. In case of the 1x1 cells, the average buckling strength of the experimental tests and FEM are 2725 N and 2681 N, respectively. It is only 1.6 % lower than experimental tests. However, after large deformation, a difference with regard to its slope was shown. This difference can be explained mainly by manufacturing process and geometrical differences. Since the spacer grids are formed by welded strips at their intersections to form grid cells, there exist some deviations. Additionally, the special geometries such as a spring and dimple can't be modeled exactly in two dimensional space.



(a) 1x1 cell

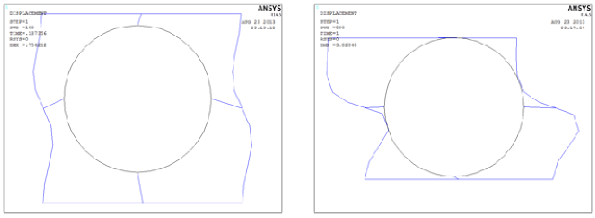


(b) 3x3 cell

Fig. 4 Load-displacement curves

Fig. 5 shows the deformed shapes of the 1x1 cell after the compression test and the geometry obtained by the FEM analysis. Based on the load-deflection curves and deformed shape results, it can be said that the FE modeling and analysis are acceptable.

(a) Experimental result



(b) FEM result

Fig. 5 Deformed shapes after compression

3. Conclusion

A study was conducted to develop the simplified model of a spacer grid and provide a prediction of buckling behavior. The FE analysis results are quite similar to the experimental tests.

- The deformed geometry of FE model after compression is consistent and very similar to that of real situation, and the non-linear analysis method used in this model can simulate buckling and post-buckling behavior well.
- The buckling strength obtained by FEM shows a very good agreement with the physical tests.

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