*Transactions of the Korean Nuclear Society Autumn Meeting*
*Gyeongju, Korea, October 29-30, 2009*

# Experimental Characteristic Analysis of 4x4 Partial Supporting Structures for a Dual-Cooled Fuel

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## 1. Introduction

Spacer grid assemblies are known as a key structural element in the fuel assembly design. Their structural and thermal/hydraulic functions are to provide both lateral and vertical support for the fuel rods, to maintain fuel rod spacing, and to enhance coolant mixing, etc. Recently, a dual-cooled fuel (i.e. annular fuel) that has both internal and external cooling has been proposed. It would allow a substantial increase in power density and safety margins compared to a solid fuel in operating PWR plants [1]. In order to satisfy the sufficient cross-sectional area of the internal cooling channel and an amount of fuel pellet, the diameter of an outer tube should be increased for applying the essential concept of the dual-cooled fuel to current operating PWRs. However, it results in a narrow gap between a dual-cooled fuel rod and its supporting structure due to a fixed fuel assembly size. So, it is reasonable that the positions of supporting structures around the dual cooled fuel rod should be modified from the rod-to-rod center to sub-channel regions of grid structure.

From the results of analytical methods for considering the advantages of current spacer grid technologies [2], various conceptual designs for supporting structures were proposed and three kinds of 4x4 partial supporting structures were manufactured such as cantilever, embossing and insertion types. In this study, the characteristic analysis of 4x4 partial supporting structures is performed by using a new test rig. The objective is to examine the characteristics of the manufactured 4x4 partial supporting structures in order to verify the supporting behavior at the contact regions before actual Zirconium supporting structures.

## 2. Experimental Procedure

### *2.1 Test Rig and Specimen*

A test rig for evaluating the characteristics of various supporting structures was developed [3] and this system consists of a low-speed servo motor, force sensor, displacement sensor, etc. Three kinds of 4x4 partial supporting structures were manufactured by using 304 stainless steel plates with a thickness of 0.5 mm as shown in Fig. 1. The cantilever and embossing shapes were manufactured by the pressing with specific molds while the cylindrical insertion with thickness of 0.2 mm was installed and welded at the both the edge points in the insertion type.

(a) (b) (c)

Fig. 1. Three kinds of 4x4 partial supporting structure specimens manufactured by improving the current spacer grid technologies of the solid fuel: (a) Cantilever type; (b) Embossing type; (c) Insertion type.

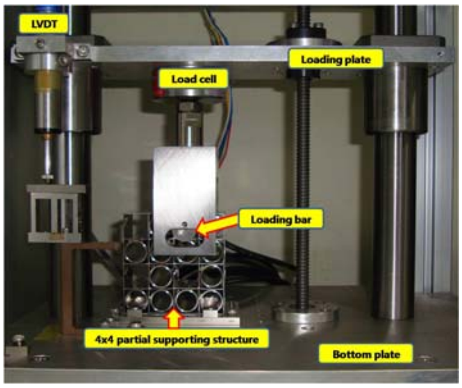


Fig. 2. Designed test rig for examining the characteristic analysis of a 4x4 partial supporting structure.

### *2.2 Test Conditions*

A 4x4 partial supporting structure specimen with fuel rods was installed on the bottom of the test rig as shown in Fig. 2. After this, the initial loading position was carefully adjusted by the handling of both the loading bar and a servo-motor controller in order to be set to a zero position. In this experiment, a loading speed was set to 1.0 mm/s and tests were performed until the maximum load was reached of 30 N. The stiffness value was calculated in the range of 5~25 N from results gained from tests repeated five times.

## 3. Results and Discussion

Fig. 3 shows the typical results of the characteristics of each 4x4 partial supporting structure specimen. As a result, the stiffness of cantilever type has a lower value (68.9 N/mm) when compared with that of the embossing (1327.1 N/mm) and insertion type (1806.1 N/mm). In the cantilever type, however, the slope of the load-displacement curve was gradually increased and then rapidly increased when the displacement was reached to about 0.3 mm. This result indicates that the loading bar was in contact with the plate of the supporting structure after the cantilever shape of the supporting structures was push down by the loading bar. In the embossing and insertion types, the reaction force showed good linearity with the applied displacement.

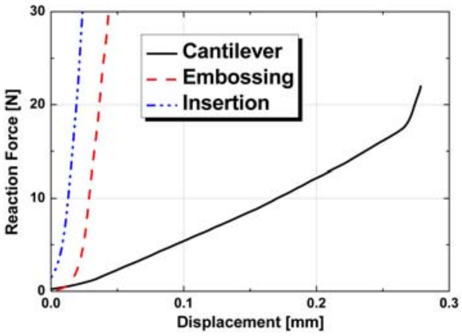


Fig. 3. Typical results of the load-displacement experiments at each 4x4 partial supporting structure.

Table I: Summary of test results [N/mm]

| | Cantilever | Embossing | Insertion |
|---|---|---|---|
| 1st | 68.6 | 1039.5 | 1521.3 |
| 2nd | 66.7 | 1437.6 | 1737.9 |
| 3rd | 70.7 | - | 1916.9 |
| 4th | 69.7 | - | 1880.0 |
| 5th | - | 1504.1 | 1976.0 |
| mean | 68.9 | 1327.1 | 1806.4 |

The evaluated stiffness values of each 4x4 partial supporting structure were summarized in Table I. With increasing the number of characteristic tests, their stiffness values are gradually increased and each zero position was drifted to the positive value. It is apparent that each supporting shape was slowly deformed under the load of 30 N regardless of the stiffness values of each supporting structure. In addition, the contact force for supporting a dual-cooled fuel rod should be increased in proportion to its mass as the mass of the dual-cooled fuel rod is heavier than that of the current solid fuel rod. Therefore, it is expected that the cantilever type of supporting structure is inadequate to support the dual-cooled fuel unless its stiffness is modified. Based on the above results, the shape and position of each supporting structure (i.e. cantilever, embossing and insertion) was expected to modify by comparing it with the results of FE analysis.

### 4. Conclusions

The characteristic analysis of 4x4 partial supporting structures is performed by using a new test rig and the load-displacement curves are evaluated. The stiffness of cantilever type has a lower value (68.9 N/mm) when compared with that of embossing (1327.1 N/mm) and insertion type (1806.1 N/mm). Based on the above results, the shape and position of each supporting structure was expected to modify in comparison with the results of FE analysis.

### ACKNOWLEDGEMENTS

This study has been carried out under the Nuclear R&D Program by Ministry of Education, Science and Technology in Korea.

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