Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Lateral Bending Characteristic Analysis of a 16 by 16 type PWR Fuel Assembly using Test Method

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1. Introduction

This paper deals with the lateral bending analysis of a PWR fuel assembly (FA). The purpose of the fuel assembly lateral bending analysis is to obtain the static stiffness characteristics of an axially preloaded fuel assembly with the top and bottom nozzles constrained within core boundary conditions in Fig.1. The test results will be used to verify the dynamic bending characteristics of a fuel assembly for the validity of the FAMeCT [1].

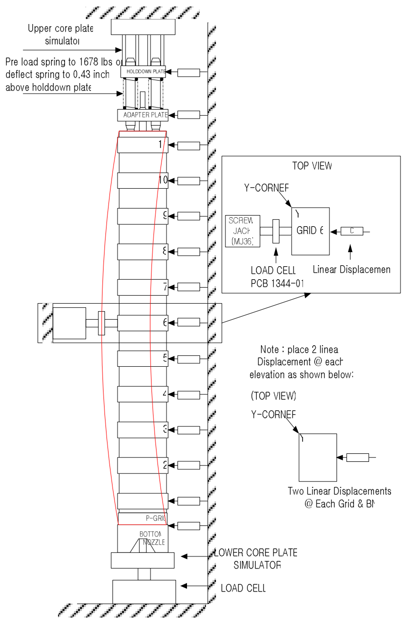

Fig. 1 Schematic diagram of the lateral impact test arrangement.

2. Static Bending Test of a 16by16 Type Fuel Assembly

2.1 Test Arrangement

The fuel assembly was positioned vertically in the test stand and restrained at the top and bottom nozzles with core plate simulators typical of a reactor support conditions. The fuel assembly was axially pre-loaded to approximately 7470 N by compressing the top nozzle hold-down springs to simulate a beginning of life (BOL) hot condition [2].

The 26 linear transducers were placed at the top, bottom and 11 grid positions except the bottom grid position. And two dial gages positioned at the bottom surface of the upper core plate simulator and the rear side of the screw jack for loading condition. In addition to this, the 108 single directional strain gages mounted on the thimble tubes after skeleton fabrication and prior to fuel rod insertion. The location, quantity, and the numbering of each strain gages mounted on the thimble tubes are shown in Figure 2. One hundred eight strain gages were mounted on the Zirlo® thimble tube surfaces. The gages were mounted at the specified locations such that the bending strains can be obtained for the lateral stiffness test. Two gages per thimble were laid 180 degrees apart to obtain the membrane and bending strain levels for the lateral load test. A corner thimble location strain was measured at each span location to obtain the axial load distribution relative to span. Five thimble tubes were instrumented near the middle and lower span of the fuel assembly to generate a load distribution at these locations.

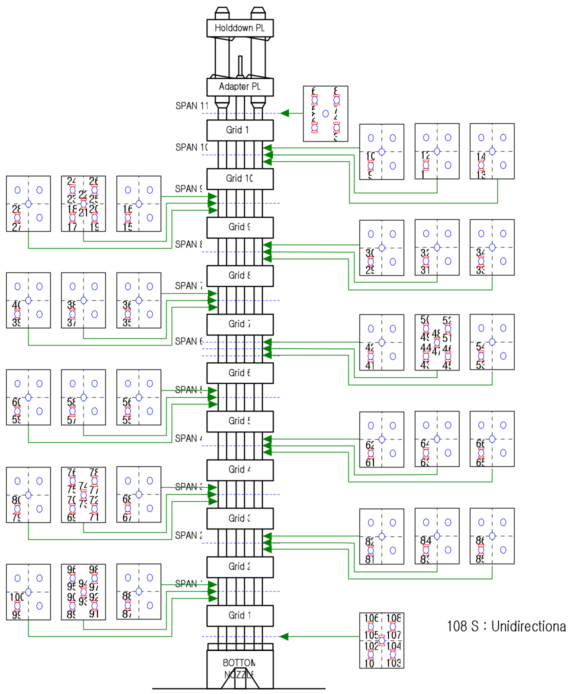

Fig. 2 Strain gage numbering of a fuel assembly for static bending test.

2.2 Test Results

The lateral stiffness characteristics of a 16 by 16 type fuel assembly were obtained from the lateral bending tests conducted in air and room temperature condition. The lateral loads were incrementally applied and removed at the grid sixth elevation, which was portrayed in Figure 3. The load versus deflection characteristic curve was non-linear for these tests due mainly to fuel rod slippage. The assembly did not return to its original position when unloaded due to frictional forces of the fuel rods. So the remain displacement due to initial deflection was approximately 6 mm. This apparent set was removed by manually shaking the fuel assembly. Each test was repeated as the same test procedure. The average effective lateral stiffness versus grid displacement for loads applied at sixth grid elevation was shown in Figure 4. The lateral stiffness was obtained the highest at the fifth grid position from the start to 40 mm deflection [3]. After that, the sixth grid position had the highest elevation. The results were caused due to the friction forces at the third grid position and a sequence of the tests. The seventh grid position showed the smallest stiffness at the each deflection.

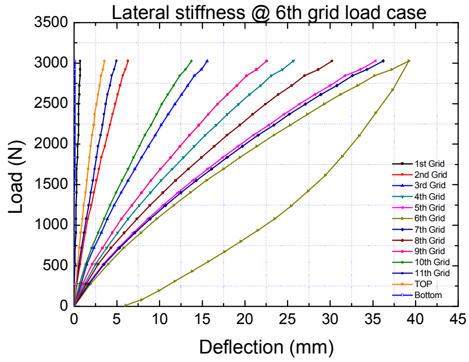

Fig. 3 Lateral stiffness at the grid sixth position loading

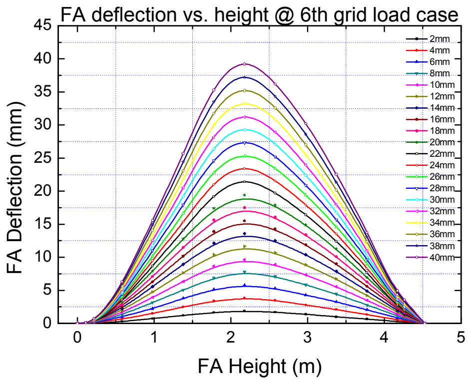

Fig. 4 Lateral load vs. deflection curve of 40 mm displacement case at 6th grid

The bending strains were calculated from the individual strain gage readings on each side of the guide thimble (GT). The bending strain values were approximately linear behavior with respect to the grid lateral displacement and display the strain distribution along the length of the fuel assembly. In this case, the maximum bending strain occurred at the below region of the flange. The maximum bending strain at the over the P grid region of the outer GT E was nearly same value with the front side GT B. The bending strains of the GT A at the every elevation were shown in Figure 5. In this Figure, most of the strain values of the each grid position were linearly increased as the lateral deflection of the sixth grid elevation. The maximum bending strain was 1257.5 με, and the maximum bending stress was 124.8 MPa.

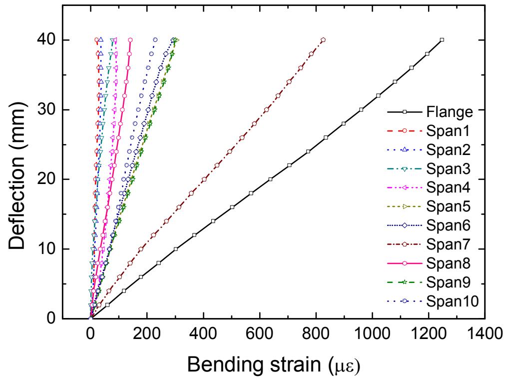

Fig. 5 The bending strain as the each grid position from the lateral bending test.

3. Concluding Remarks

The lateral bending analysis of a 16 by 16 type PWR fuel assembly by using the test method is executed. The universal test facility for the various test of the fuel assembly properly is established. The maximum bending strains are nearly same with the previous those by other test facility. However, the measured stress level is much lower than the yield strength of the Zirconium material. Therefore, the maximum lateral displacement 40 mm is no problem for repeated test procedure.

Acknowledgement

This work was financially supported by the nuclear R&D program from the Ministry of Science and Technology of Korea. Authors are grateful to the KNFC for lending the test assembly.

References

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