Development of Simplified Beam/Truss Model for Vibration Analysis of LWR Fuel Assembly

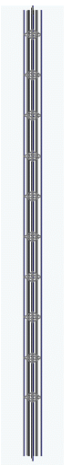
Sang Soon Lee*, Han Cheal Kim*, Kyung Ho Yoon**, Hyung Kyu Kim**
** School of Mechatronics Engineering, Korea University of Technology and Education*
sslee@kut.ac.kr
***PWR Fuel Development, KAERI,150 Dukjin, Youseong, Daejeon,*

1. Introduction

This paper deals with the computer model, which will be used vibration analysis of LWR fuel assembly. The computer model should be verified by the equivalent test results. KAERI constructed the test facility, called the Fuel Assembly Mechanical Characterization Tester (FAMeCT), to carry a series of dynamic mechanical tests to determine the structural characteristics of the nuclear fuel on a full size model basis. These test series cover vibration, impact and stiffness characteristic tests in air. The computer model is developed by ANSYS and compared to the test results.

2. Methods and Results

Figure 1 shows a simplified beam/truss model for a fuel assembly. The four thimble tubes and one instrumentation tube are modeled with 3-dimensional beam element. There are 236 fuel rods in a fuel assembly. The four representative fuel rods are employed to model the mechanical behavior of all fuel rods. The four fuel rods are modeled with 3-dimensional beam element. Beam element requires the following real constants: area, moment of inertia, and thickness. The numerical values of the real constants are not listed here. The four different grid types are represented by 3-dimensional truss elements. Figure 2 shows the finite element model for vibration analysis.



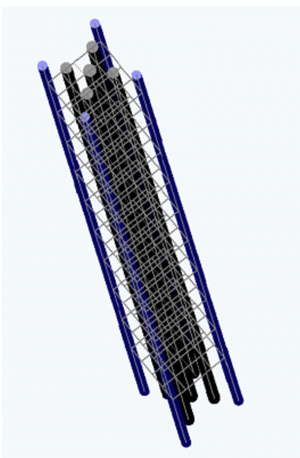


Figure 1. Simplified beam/truss model for vibration analysis

To verify the accuracy and effectiveness of the proposed model, the fuel assembly has been tested in air, room temperature for estimating the lateral vibration characteristics using a sine swept testing. Details of vibration tests can be found in Ref. [1,2]: however, a brief review of such test is in order.

The fuel assembly was positioned vertically in the test stand mounted on a vibration isolation base and restrained at the top and bottom nozzles with core plate simulators of the reactor core support conditions as in figure 3. The test assembly was axially pre-loaded to 15 mm hold-down spring deflection to approximate in-core BOL hot condition. Strain gauge type linear gauges were used at each grid location to measure the lateral displacement. During the swept sine testing, an electro-magnetic shaker was attached to the fuel assembly at the 6th grid location to apply the shaking force through the metal stinger. The schematic of the overall test is also shown in figure 3. The shaker input force was varied from 2N to 20N. The shaker output frequency was varied from 1.0 to 30 Hz at a log sweep rate of 1 octave/period. The input from an electromagnetic shaker and the output from the linear gauges were stored on a data acquisition system (SYSTEM 6000) and were analyzed using I-DEAS TDAS.

The fundamental natural frequency and mode shape can be obtain from modal analysis of sine post processing using I-DEAS TDAS software and time domain modal estimator of the MTS Reporter software. Table 1 shows natural frequencies obtained from the simplified beam/truss model. The numerical results using the simplified beam/truss model show very good agreement with the experimental results. This demonstrates that application of the simplified beam/truss model leads to very accurate and efficient numerical solutions. Figure 4 shows the mode shapes.

3. Summary and Conclusion

A simplified beam/truss model has been developed by ANSYS and compared to test results. The four thimble tubes and one instrumentation tube are modeled with 3-dimensional beam element. The four representative fuel rods are modeled with 3-dimensional beam element. The four different grid types are represented by 3-dimensional truss elements. Sine swept testing for investigating the vibration behavior of the fuel assembly was performed. The numerical results using the simplified beam/truss model show very good agreement with the experimental results. This demonstrates that application of the simplified beam/truss model leads to very accurate and efficient numerical solutions.

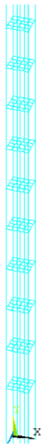


Figure 2. Finite element model for vibration analysis

Acknowledgements

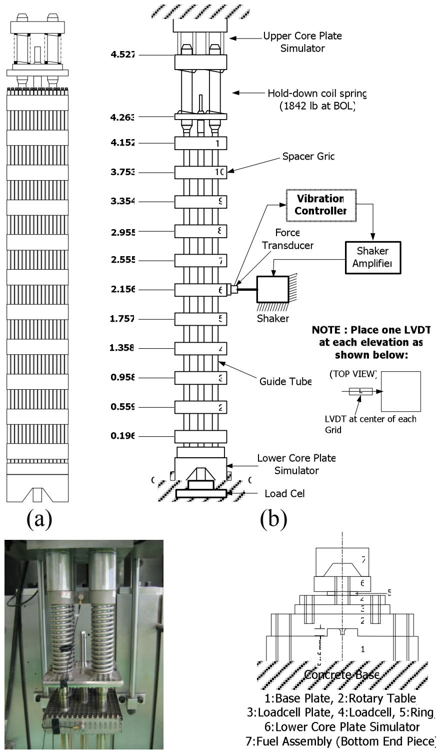
This project has been carried out under the nuclear R&D program by MOST.

References

[1] K.H. Lee et al., Vibration characteristics of the grid cage assembly, Proceedings of Korea Nuclear Society, Fall, (2005)
[2] H. K. Kim et al., Test and analysis of LWR fuel assembly mechanical behavior, Proceedings of KSME Spring, (2006).

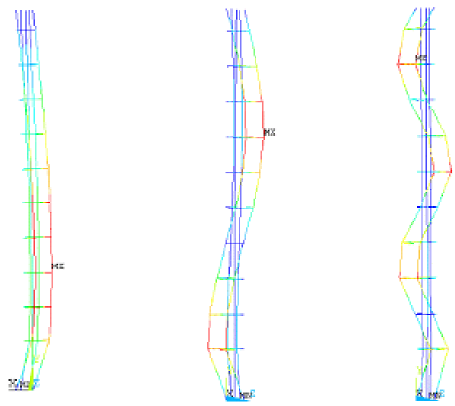
Table 1 Comparison of natural frequencies obtained from finite element analysis(FEA) and vibration test.

Mode		1st	2nd	3rd
2 N	FEA	2.39	4.63	9.94
	Test	2.41	4.22	9.08
5 N	FEA	2.27	4.34	9.0´
	Test	2.20	3.32	9.03
10 N	FEA	2.13	3.98	8.03
	Test	2.12	4.17	8.88
15 N	FEA	2.06	3.79	7.47
	Test	2.04	4.01	8.83
20 N	FEA	2.03	3.67	7.13
	Test	1.98	4.00	8.65



(c)

Fig. 3 (a) Schematics of the fuel assembly, (b) test setup for grid cage assembly, (c) upper and lower core plate simulator.



(a) (b) (c)

Fig. 4 Vibration mode shapes obtained from finite element analysis ;(a) 1st mode, (b) 2nd mode, (c) 3rd mode.