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Forced Vibration Test of The Fuel Assembly at EOL Condition

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1. Introduction

The EOL (End of Life) condition of the nuclear fuel causes the gap between the fuel rods and the grid to increase due to the expansion of the fuel paths and the relaxation of the grid spring and dimples during the combustion process under high temperature and high pressure.[1] Therefore, during an earthquake and LOCA (Loss-Of Coolant Accident) the gap decreases and the stress and impact load on the nuclear fuel assembly may increase compared to the BOL (Beginning of Life) condition. during an SSE (Safe shutdown Earthquake) and LOCA. In addition, the impact resistance of the grid is also decrease. Which reduces the buckling strength. For these reasons, regulatory agencies often require an evaluation of the seismic performance of EOL condition nuclear fuel when licensing new nuclear power plants, both domestically and internationally. In this paper, we investigate the mechanical properties of the forced vibration of the EOL condition nuclear fuel assembly in air, in preparation for inquiries from regulatory inquiries regarding the continued operation of nuclear plant units, the test data will be used for model development and as input data for future earthquake and LOCA analyses.

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2. Forced Vibration Test Facility

The mechanical tests of the nuclear fuel assembly in air by KEPCO Nuclear Fuel are to be conducted at the mechanical characteristics test facility (TOFAS-A). TOFAS-A is a test facility designed and built to perform static and dynamic tests on a single bundle of test fuel assembly. The facility has a three-storey workbench and can accommodate test specimens in a test section measuring 0.9 m in width, 1.5 m in length, and 6.0 m in height. At the rear of the test section, a 90 mm thick steel plate and reinforced concrete are installed to minimise acceleration and displacement that may occur during various tests such as bending and impact of the nuclear fuel assembly. The 90 mm thick steel plate has six railways to install jigs for testing the static and dynamic characteristics of the nuclear fuel assembly. A jig capable of supplying a hold down force of 35 kN (with a stroke distance of 350 mm) is installed on the railway. Additionally, a motor capable of applying a load of 4 kN and providing a movement of 150 mm is installed to bend the nuclear fuel assembly laterally. The lateral deformation jig is equipped with an electromagnet that can instantaneously release magnetic force to create lateral free vibrations. The detailed specifications are as follows and may vary depending on the type of test and the required test range.

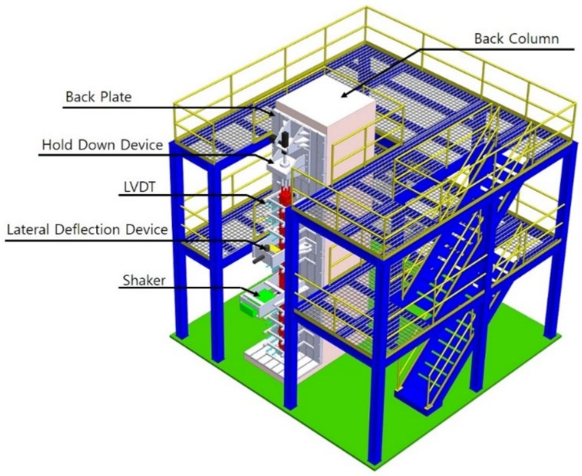

Fig. 1. Structure of the Fuel Assembly Forced Vibration Test Facility (TOFAS-A)

The measurement and signal processing equipment (DAQ, Data acquisition) for the fuel assembly mechanical test facility in air is shown in Table 1. The sensor applied may vary depending on the type and conditions of the test. All measuring equipment used is calibrated by accredited institutions and managed under QA system.

Measurement Equipment	Manufacture	Model	Measurement Range
DAQ	LMS	LMS SCADAS Lab	
LVDT	RDP	RDP DCTH Series	± 50 mm, ± 25 mm, ± 5 mm
Load Cell	HBM	U10 Series	± 25 kN
	HBM	U9C~5K	200 N, ± 1 KN, ± 5 kN
	Bongshin	DSCK-20T	- 200 kN

Table. 1. Major Measurement Equipment for the Fuel

Assembly Forced Vibration Test Facility in air (TOFAS-A)\

3. Forced vibration Test of the Fuel Assembly

The purpose of the forced vibration test is to determine the natural frequencies and mode shapes of the EOL simulation fuel assembly. The result of this test will be used to create a detailed air model of the fuel assembly. Fig. 2 shows a schematic core plate of the forced vibration test using LVDTs, a displacement measuring device, in addition to a vibrator, which functions as a load input device. LVDTs are capable of measuring vibrations from upper and lower support grid (4MG or 5MG). These LVDTs are located within the confines of the nuclear fuel assembly. The test apparatus has been designed to simulate the upper and lower core plates. The pressing force was applied to the pressing spring upper core plate. A sine wave with a continuous time response was applied to the 3rd mid grid and the 4th mid grid (4MG or 5MG). Fig. 3 shows the frequency response spectrum of the specific displacement in the frequency domain that occurred when the 3rd and 4th mid grid (4MG or 5MG) were excited with a compressive load. The peak was not clearly defined at the location of the 4th mid grid (5 MG) due to its proximity to the nodal point.

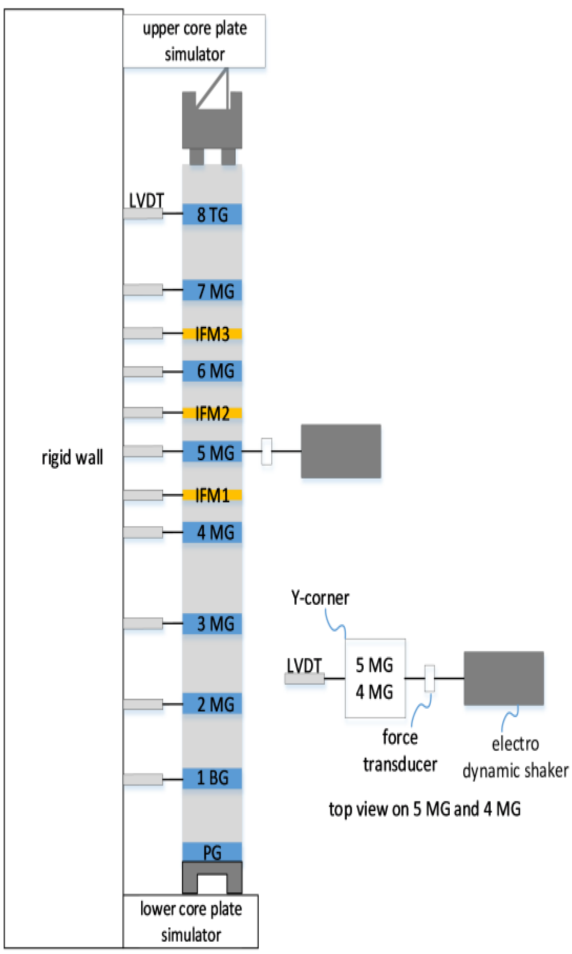

Fig. 2. Structure of the Fuel Assembly Forced Vibration Test

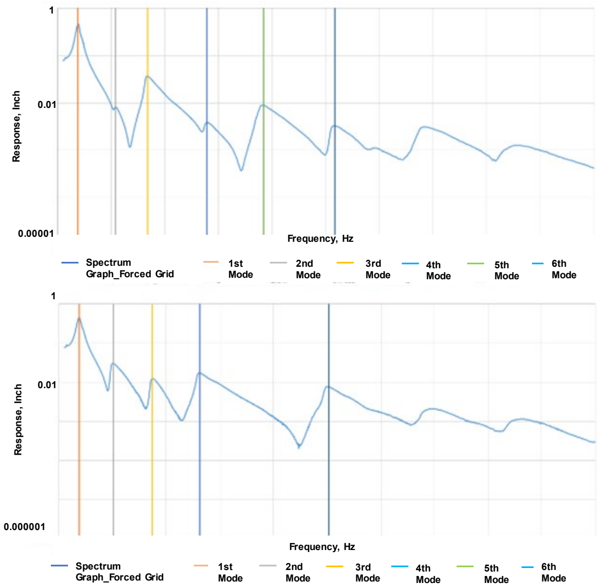

Fig. 3. Forced Vibration spectrum of Fuel Assembly at EOL condition (up: 4 MG, down: 5 MG)

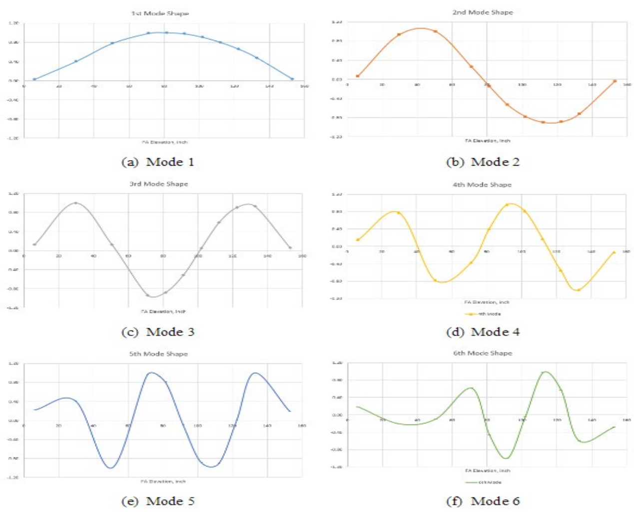

Fig. 4. Forced Vibration mode shape of Fuel Assembly at EOL condition

4. Conclusion

A forced vibration test was carried to measure the response to sinusoidal excitation using a vibrator. The measurements showed an increase in the 1st and 6th eigenfrequencies. This result is consistent with the observation that the bending test displacement increased both the 1st and 6th eigenfrequencies. The frequencies, determined from the forced vibration test will be used to develop a detailed model for seismic analysis of nuclear fuel assemblies.

Acknowledgement

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REFERENCES

[1] N. G. Park, O. C. Kwon, B. L. Kim, and J. S. Yoo, Korean Society for Precision Engineering 2019 Spring Conference, p. 414, 2019