# SMART100 Fuel Assembly Vibration Test at End of Life

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## 1. Introduction

SMART(System-integrated Modular Advanced ReacTor) 100 is an advanced small sized nuclear power reactor, which adopts various inherent and passive design feature to achieve enhanced safety and improved economics compared to commercial nuclear power plants. As shown in Fig 1, SMART100 fuel assembly consist of removable top nozzle, each grid, lower pressure drop bottom nozzle, guide tube and 17×17 array fuel rod. This fuel assembly is designed to be satisfied with 0.3g seismic criterion at beginning of life(BOL) and end of life(EOL) conditions. The structural integrity of fuel assembly is evaluated through the finite element method(FEM). However, the mechanical tests of fuel assembly shall be preceded to verify mechanical characteristics of finite element model. Thus, in this study, to obtain the SMART100 fuel assembly dynamic characteristics such as natural frequencies, mode shapes and damping, the test procedure and test result are described with respect to lateral vibration test of SMART100 fuel assembly at EOL condition.

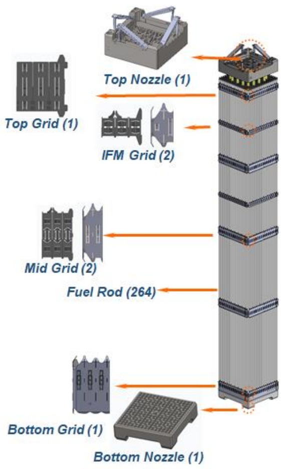



Fig. 1 SMART100 fuel assembly

## 2. Test

### *2.1. Test Equipment*

SMART100 Fuel assembly vibration tests have been performed in TOFAS-A. TOFAS-A is a test facility built in KNF for FA-wise tests such as static and dynamic tests. Also, it is possible to identify the fuel assembly mechanical characteristics such as natural frequency and bending stiffness of fuel assembly in air condition by using TOFAS-A. As shown in Fig 2, this facility can mount fuel assembly that reflected in core boundary condition on the test bed.

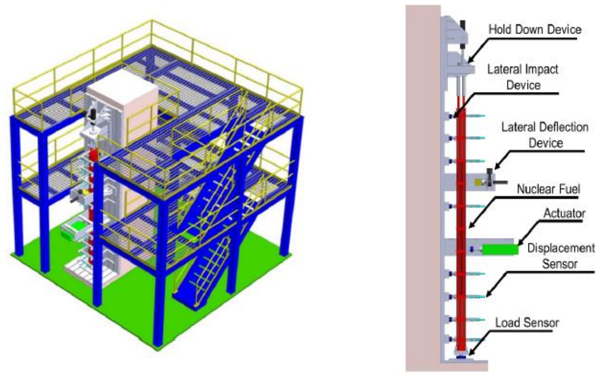



Fig. 2 TOFAS-A facility configuration

The vertical test bed consists of a thick steel plate and a concrete structure which are capable of installing various instruments for fuel assembly. The general specification of TOFAS-A is summarized in Table 1.

Table 1 General specification of TOFAS-A

| TOFAS-A |
|---|
| - 6m × 6m × 6.5m Size (3 Stories)<br>- 1.5m × 1.5m × 6.5m Reinforced Concrete<br>- 90mm Steel Backboard<br>- 6 Rail Ways for Movable Measurement<br>- 35kN Hold Down Force<br>- 4kN Lateral Deflection Force |

### *2.2. Test Configuration*

The schematic of SMART100 fuel assembly, instrument, shaker, measurement position, and structure are shown in Fig 3 as mechanical test in air condition. The excitation or deflection were applied to the 3rd (central, 2nd mid) grid of the fuel assembly and the output of loadcell and linear variable differential transformers (LVDTs) were recorded on the hard disk according to the test.

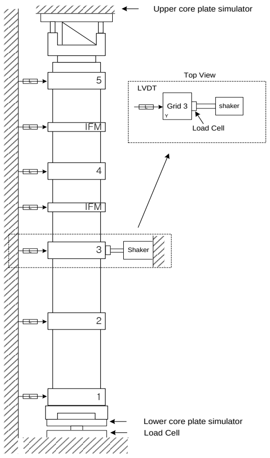



Fig. 3 Schematic of Lateral vibration test

### *2.3. Test Method*

As shown in Fig 3, SMART100 fuel assembly was positioned vertically in the test stand and restrained at the top and bottom nozzles with core plate simulators typical of reactor support conditions. The fuel assembly was axially pre-loaded to accomplish EOL hot condition. LVDTs were used at each grid location to continuously monitor any lateral displacement. During the forced vibration test, an electrodynamic shaker was attached to the fuel assembly's 3rd (central) grid to apply a sinusoidal force and excitation frequency which are mentioned in detail below Table 2 to obtain the modal frequencies and mode shapes. After the forced vibration test, a mechanical actuator was installed at the 3rd (central) grid location for the required initial deflections for pluck vibration test. The mechanical actuator was connected to the fuel by a magnetic, and the locking by magnetic was shortly removed after the desired initial deflection which is mentioned in Table 3 was reached.

Table 2 Lateral vibration test

| Test Method | Excitation load | Measurement variables |
|---|---|---|
| | Excitation frequency | |
| Shaker control | 10 ~ 80N[1)] | • Lateral excitation load |
| | 0.5 ~ 100Hz | • Lateral grid deflection |

*1) Increase excitation load in 10N increments from 10N until maximum excitation load of 80N*

Table 3 Pluck vibration test

| Test Method | Initial deflection | Measurement variables |
|---|---|---|
| Magnetic release | 5 ~ 20mm[2)] | • Lateral grid deflection |

*2) Increase initial deflection in 5mm increments from 5mm until maximum initial deflection of 20mm*

### *2.4. Test Result*

The natural frequencies, mode shapes, and damping values of SMART100 fuel assembly were obtained from test data conducted in air at room temperature. The input from the electro-magnetic shaker and the output from the LVDTs were analyzed using a spectrum analyzer. A frequency response spectrum with respect to the lateral displacements of fuel assembly according to the frequency is shown in Fig 4.

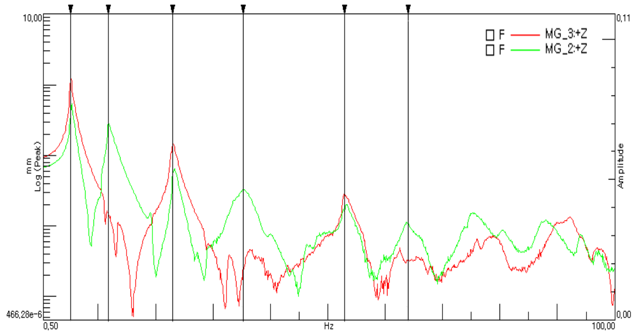



Fig. 4 Frequency response spectrum

The natural frequencies of the fuel assembly are determined through the peak characteristics of the frequency response spectrum without analysis and calculation process. Thus, based on the frequency response spectrum, the normalized natural frequencies and mode shapes of the fuel assembly are shown in Fig. 5 and Fig. 6

The lateral mechanical damping for the fundamental mode were obtained from the test results. The fundamental frequency and the corresponding structural damping versus the single peak displacement are shown in Fig. 7. The critical damping ratio were computed through the logarithmic decrement ($\delta = \ln X_1/X_2$) method. The logarithmic decrement represents the rate at which the amplitude of a free-damped vibration decrease. It is defined as the natural logarithm of the ratio of any two successive amplitude [1]. Thus, the critical damping ratio of fuel assembly for the fundamental natural frequency were a function of vibration amplitude. As a results, the damping values range from 3.7 to 8.7 percent of the critical damping.

## 3. Conclusion

In this study, the lateral vibration tests of the SMART100 fuel assembly were performed to find out the dynamic characteristics, and the test procedures, method and results were describes. In the near future, a 3D finite element model for evaluation of the fuel assembly integrity will be developed through the test results such as natural frequencies and mode shape.

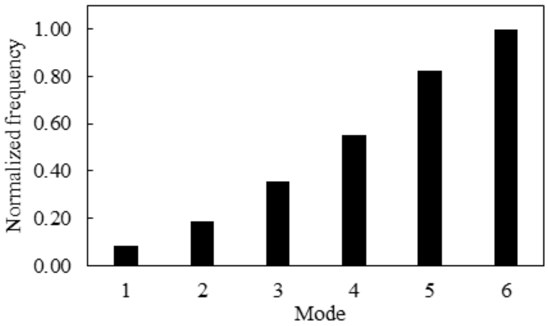
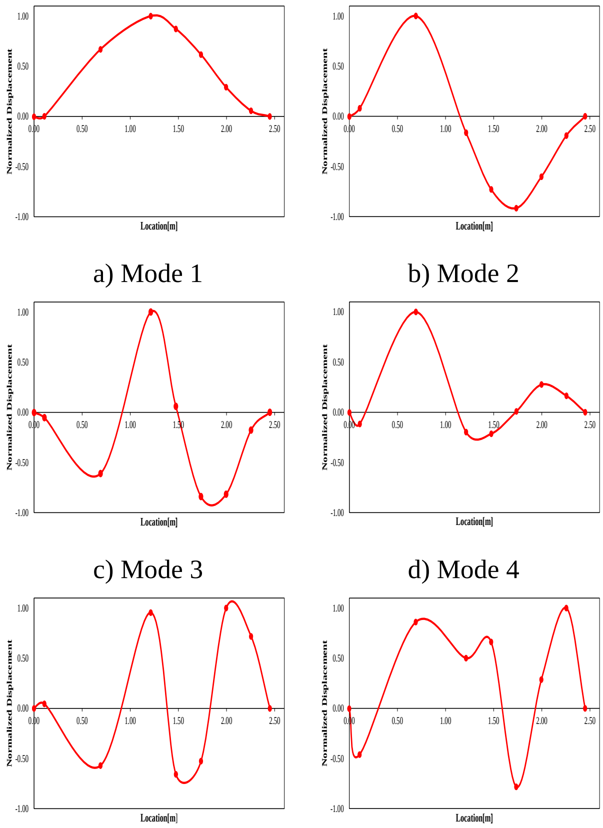



Fig. 5 Normalized natural frequency




a) Mode 1 b) Mode 2

c) Mode 3 d) Mode 4

e) Mode 5 f) Mode 6

Fig. 6 Mode shape

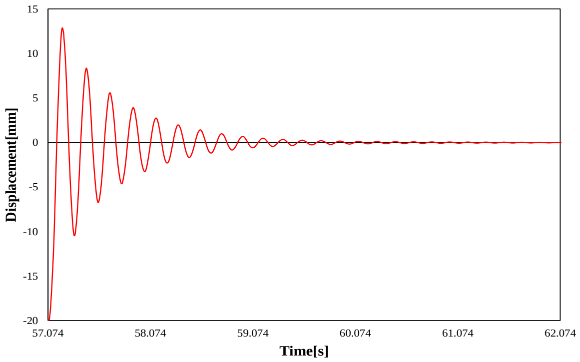



Fig. 7 Pluck vibration of the fuel assembly

## REFERENCES

[1] S. S. Lao, Mechanical Vibrations, Pearson Prentice Hall, 2004.