Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2017

Vibration Tests for PWR Fuel Assemblies Submerged in Still Water with a Modal Shaker and a Seismic Shaker

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1. Introduction

Fukushima accident, which was recorded 9.0 magnitude earthquake followed by significant tsunami, draws attention to the public on Beyond Design Basis Accidents (BDBA). It was known that the Peak Ground Acceleration by the earthquake was recorded to be 0.561g that was the beyond the design bases of the Dai-ichi NPP 2, 3, and 5. The maximum design basis of Dai-ichi NPPs is 0.43g [1].

As a researcher who is working for the structure development of fuel assembly, and its structure integrity, a question would be asked whether or not the integrities of the fuels are alright after the severe shock, followed by impacting occurred in fuel-to-fuel, and fuel-to-core shroud.

In order to design and analyze the structural integrity of fuel assemblies during transients, such as a beyond design basis seismic accident, and loss of coolant accident, as well as normal operation, some structural characteristics of the fuel assembly should be required. A difficult thing is that the characteristics of the fuel assembly is acquired only from real-sized dummy fuel assembly. In the early development stage of nuclear power plant, the characteristics of the fuel assembly were obtained from a structural test under an air environment. Recently, however, the characteristic test is required to be performed under water environment, even in flowing water[2,4]

In this study, we report some structural characteristics of a PWR fuel assembly obtained from a vibration test under a water environment with a seismic shaker as well as a modal shaker. The characteristics are a lower few of natural frequencies, mode shapes and damping. For the vibration test, high performance fuel was used for a seismic shaker test, and a dual-cooled fuel, which had been developed by KAERI

2. Vibration Characteristic Test

2.1 Test Setup

For the vibration characteristic test, a water reservoir that can contain single fuel assembly was built from transparent acryl for a modal shaker, and steel plates for a seismic shaker. Fig.1 and Fig.2 show the photography of the reservoirs that contain dummy fuel assemblies.

In order to obtain the vibration characteristics of fuel assembly, a single shaker, and water-proof accelerometers are used: three accelerometers for a modal shaker test, and 8 accelerometers for a seismic shaker test, respectively. A force sensor was used for the modal shaker test to control the shaking force. However, no force sensors was used for the seismic shaker test. The seismic shaker was operated to control shaking acceleration and displacement: acceleration of 0.1g with displacement of 3mm and 0.2g with 5mm.

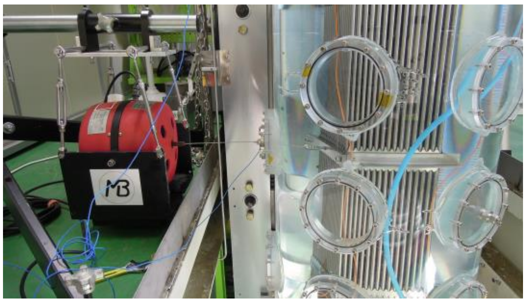


Fig. 1 Vibration Test with Modal Shaker

Fig. 2 Vibration Test with Seismic Shaker

2.2 Test results

Transfer functions (T.R. = acceleration/force) from the air and water tests disclose different natural frequencies, which was shown in Fig. 3. Mode shapes are shown in Fig 4. The natural frequencies and damping obtained from the modal shaker test are summarized in Table 1. As shown clearly in Fig. 3, an added mass effect by water lower natural frequencies at each modes as compared with the air test.

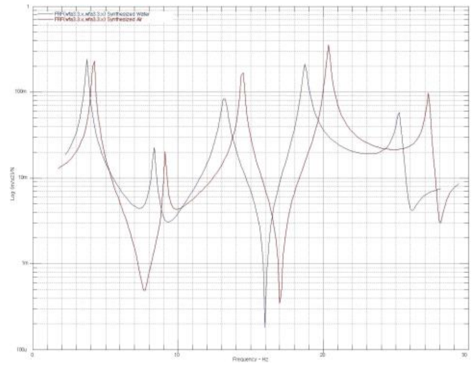
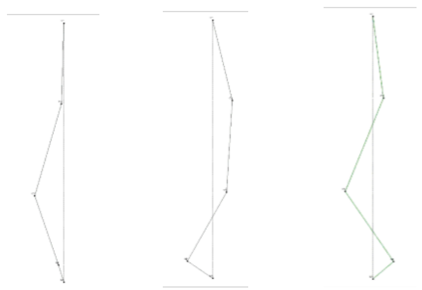


Fig. 3 Frequency Response Function for air and water environment with shaking force of 4N



(a) mode 1 (b) mode 2 (c) mode 3

Fig.4 Mode Shapes of FA in water

Table 1 Natural frequency and damping obtained from a modal shaker test

Mode	Air, 4N		Water, 4N	
	Frq. (Hz)	Damping	Frq. (Hz)	Damping
1	4.2	1.38%	3.7	2.45 %
2	9.12	0.7 %	8.36	1.3 %
3	14.45	0.65 %	13.2	1.46%

Differently from the modal shaker test, a transfer function, defined by shaking acceleration divided by the response acceleration at each point, was utilized. With a seismic shaker test, lower four modes are shown in Fig. 5. Since more accelerometers were used than the modal shaker test, much clearer mode shapes were obtained through the seismic shaker test.

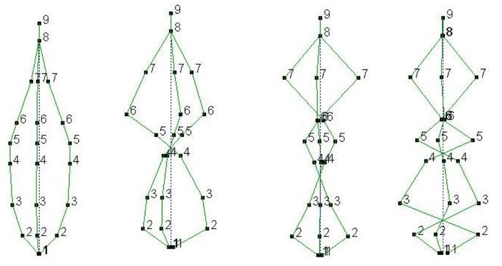


Fig. 5 Mode shapes of FA in water with 0.1g

Natural frequency and damping at each mode through the seismic shaker test are summarized in Table 2.

Table 2 Natural frequency and damping obtained from a seismic shaker test

Mode	Air, 0.1g		Water, 0.1g	
	Frq. (Hz)	Damping	Frq. (Hz)	Damping
1	3.4	3.44 %	3.0	5.2 %
2	8.0	1.86 %	7.1	2.74 %
3	12.0	1.76 %	9.2	2.14 %
4	14.6	1.91 %	12.0	1.21 %

Interesting thing is that the natural frequencies obtained from a seismic test are lower than those from a modal shaker test even though different fuel shapes are appreciated. The damping at the first mode is larger as compared to those in Table 1.

When used a modal shaker, we should install a stringer to connect the shaker to fuel assembly. We believe that the stringer added some stiffness to FA, so that natural frequency goes up somewhat. Damping also had some effects due to the stringer connection.

4. Conclusions

In this study, we performed vibration characteristic test of PWR fuel assembly in air and water not only with a modal shaker but also with a seismic shaker to obtain mode shapes, natural frequencies and damping. Dampings at the first modes from water environment are 2.45% from a modal shaker test while 5.2% from a seismic shaker test. We may expect easier and more precise results when a seismic shaker is used. It is worthy of reporting that with a seismic shaker, low natural frequencies and high damping are obtained.

ACKNOWLEDGEMENT

This research was supported by the nuclear R&D program supported by the Ministry of Trade, Industry and Energy of the Korean government (No 20141510400060)

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