Test Model for Dynamic Characteristics of a Cantilevered Simple Cylindrical Structure Submerged in a Liquid

Chang-Gyu Park *, Tae-Sung Kim, Hoe-Woong Kim, Jong-Bum Kim
Korea Atomic Energy Research Institute, Daedeok-daero 989-111, Yuseong-gu, Daejeon, 305-353, Korea
**Corresponding author:chgpark@kaeri.re.kr*

1. Introduction

The UIS (Upper Internal Structure) for an SFR (Sodium-cooled Fast Reactor) system provides lateral support and protection against the sodium flow induced vibration of the control rod drivelines. In addition, it also promotes the mixing of primary sodium as it exits the core assemblies [1]. Because it is cantilevered downward into the reactor hot pool without any horizontal support, it is vulnerable to horizontal loading such as an earthquake or coolant cross flow. Therefore, its dynamic characteristic is one of the important issues in a reactor internal structure design.

While the upper part of the UIS is exposed to cover gas region for normal operating condition, the lower part is submerged in the primary coolant. Fluid contacting with the structure imposes a fluid mass on the structure, and the generated fluid added mass may affect the dynamic characteristics of the structure [2]. A coolant free surface level is dependent on the operating conditions, and thus the fluid added mass caused by contacting sodium with the structure affects the dynamic characteristic of the UIS. In this study, a numerical analysis model was proposed and a feasibility study was performed through structural testing. The dynamic characteristics for a simple cylindrical structure simulating the UIS outer cylinder will be tested. Currently, the FE analyses were carried out to confirm the effect of water chamber structure on the natural frequency of the test model.

2. Test Model and FE Analysis

2.1 Numerical Model

A numerical analysis model for dynamic characteristics was prepared to establish and compare the modal results for different water level conditions. It was carried out using the ANSYS [3] software. The element types used in the analysis were a SOLID45 element for a structure volume and FLUID30 element for a water volume. The target structure model used in the numerical analysis has a cup-shaped structure. Its inner radius and thickness are 10.3cm and 3.5mm, respectively. The inner radius of the water chamber is 19.5cm, and it was assumed to be a rigid body without any fixed condition because the support structure can affect the natural frequency.

2.2 Dynamic Structural Testing

Dynamic testing equipment was established and the tests to verify the numerical model were carried out. The test equipment was mainly composed of three parts; i.e., the test model, front-end, and signal analyzer. The front-end equipment is an LMS SCADAS Mobile SCM02, and the signal analyzer is an LMS Test.Lab 12A. An impact hammer was used for the excitation. The tests were performed for the air condition and 50% submergence was performed for the water condition. The test equipment was installed as shown in Fig.1, and Table I shows the comparison of the results. As shown in Table I, both results were very close, and thus the numerical model proposed was valid for the dynamic characteristics of the submerged cylindrical structure.

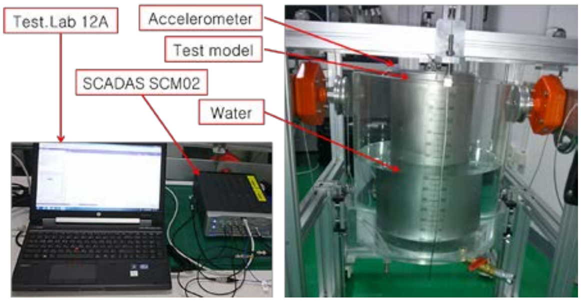


Fig. 1. Dynamic characteristic test for a cup-shaped structure to verify the numerical analysis model.

Table I: Comparison of Natural Frequencies for Both Cases

Method \ mode	Air condition		50% submergence	
	numerical	test	numerical	test
1st	214.1	214.3	201.8	204.2
2nd	596.6	599.5	560.0	563.2

2.3 Simple Cylindrical Structure

The first model for a UIS dynamic characteristic test is a simple cylindrical structure simulating the UIS outer shell. This model is made of a simple cylinder and thick circular plate simulating the concentrated mass effect, which is welded to the lower end of a simple cylinder. Its upper end is assumed to be fixed. It is made of Type 316 stainless steel (316SS), and its outer diameter and thickness are 165.2 mm and 2.8 mm, respectively.

Fig.2 shows a drawing of the dynamic testing of the simple cylindrical structure. Because the upper end is assumed to be fixed, the rigid fixture will be welded to the cylinder upper end to apply the boundary condition. The rigid fixture welded to the upper end of the cylinder is supported by a support structure. The support structure is manufactured with thick steel. The water chamber is located between the test model and support structure. The water chamber should be independent of other structure to eliminate the rigidity effect caused by a connection with the other structure.

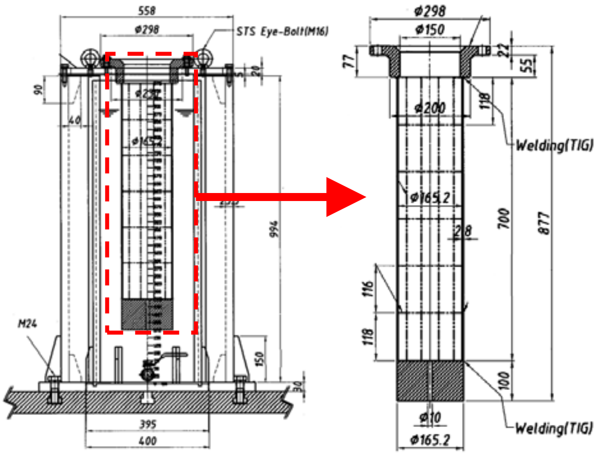
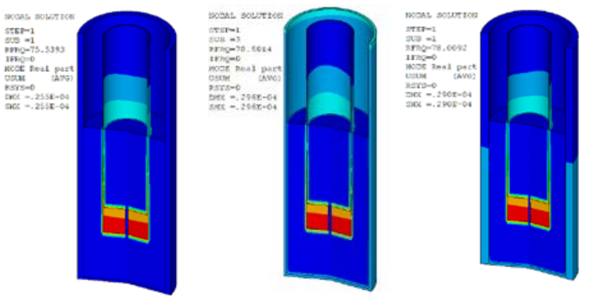
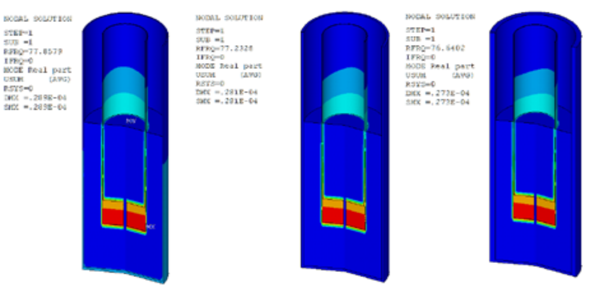


Fig. 2. Schematic drawing of a dynamic characteristic test model for a simple cylindrical structure.

The size of the water chamber is 0.32 m in outer diameter and 1.0 m in height. In this study, the effect of the water chamber condition on the natural frequency was compared through a numerical analysis based on the previous analysis method. Two kinds of materials were considered, acryl and 316SS. Both materials have a different thickness.



(a) Fixed B.C. (b) 1.0cm Acryl (c) 3.0cm Acryl



(d) 0.5cm 316SS (e) 1.0cm 316SS (f) 2.0cm 316SS

Fig. 3. Natural frequencies for a simple cylindrical structure according to the water chamber material and thickness (1st mode).

Table II: Natural Frequencies for Water Chamber Condition

Mode	Fixed B.C.	Acryl (Hz)		316SS (Hz)		
		1cm	3cm	0.5cm	1cm	2cm
1st	75.5	78.9	78.0	77.9	77.2	76.6

The reference values were calculated by considering all fixed boundary condition of the water chamber to eliminate the effect of the water chamber. Fig.3 and Table II show the analysis results for each case. As shown in Fig.3, the acryl chamber has a higher natural frequency than the 316SS case. In addition, the natural frequency of the thick wall chamber was commonly closer to the reference value. The natural frequency of the 316SS chamber is about 1.0% less than that of the acryl chamber for a 1 cm thickness. The candidate water chamber materials increase the natural frequency comparing with that of fixed model and maximum difference was about 4.5%.

3. Conclusions

The submerged condition of a UIS cylinder affects its natural frequency. A test model of a simple cylindrical structure was prepared to conduct a dynamic test, and each structure component of the test equipment may affect the natural frequency. A cup-shaped cylindrical structure was applied to develop the numerical analysis method for a structure submerged in water and it was verified through a structural test. With this numerical analysis model, the effect of the water chamber material for a simple cylindrical structure was studied. The candidate materials for water chamber were acryl and 316SS with different thicknesses. Both materials showed a higher natural frequency than the reference model. A water chamber made of 316SS with a thick wall gave a closer result to the reference natural frequency than an acryl chamber. The expected natural frequency of the test facility has about a 4% difference based on the reference value, considering a water chamber with a 1 cm thickness. This result will be verified through an ongoing future structural test activity.

ACKNOWLEDGEMENTS

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