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Dynamic Characteristics of a Perforated Cylindrical Test Structure

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1. Introduction

The Upper Internal Structure (UIS) of a Sodium-cooled Fast Reactor (SFR) is composed of several important components such as an outer cylinder, a support plate, control rod shroud tubes and instruments guidelines that must be protected from unexpected events such as an earthquake. Therefore, the dynamic characteristic analysis of the UIS is very important for the design of the SFR [1, 2]. However, because the UIS has a very complex shape and is submerged in a surrounding liquid, the realization of boundary conditions exactly the same as those in a real situation is difficult in an experiment. Therefore, the proper experimental test model is required to analyze the dynamic characteristics of the UIS more accurately.

In this study, Finite Element (FE) analyses of a perforated cylindrical structure simulating the outer cylinder of the UIS under several conditions were carried out to determine the proper experimental test model. Analyses were conducted by the commercial FE software ANSYS [3], and the mode shape and natural frequency of the test model having several flow holes were assessed for each case.

2. Finite Element Analysis of a Perforated Cylindrical Structure

2.1 Finite Element Analysis Model

An FE model for the dynamic characteristic analysis is shown in Fig. 1. It consists of a perforated cylindrical structure and a fixture. The basic size of the model is as follows; the outer diameter, height and thickness of the perforated cylindrical structure are 165.2 mm, 900 mm and 2.54 mm, respectively, and it has triangularly patterned flow holes whose outer diameters are 25 mm. The distance among centers of flow holes is 76 mm and there are total 280 flow holes including four flow holes in a bottom plate of the perforated cylindrical structure. The outer diameter, inner diameter and height of the fixture are 298 mm, 150 mm and 77 mm, respectively, and it has 12 bolting holes with 11 mm in diameter in the circumferential direction. The fixture is attached to the upper end of the perforated cylindrical structure. Materials of the perforated cylindrical structure and the fixture are all Type 316 stainless steel (SS316) and material properties used for the analysis are shown in Table I.

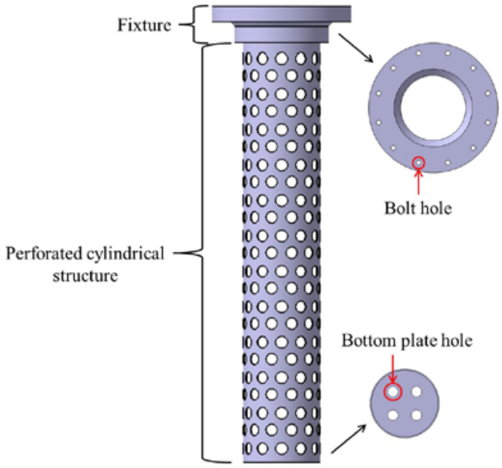

Fig. 1. Geometry of the analysis model.

Table I: Material properties of SS316

Material	SS316
Young's modulus (GPa)	195
Poisson's ratio	0.29
Density(kg/m^3)	7861.9

2.2 Finite Element Analysis

An experimental analysis of dynamic characteristics of only a perforated cylindrical structure is quite difficult because some additional structures such as a fixture and a support structure must be required to support it in an experiment. To find the proper experimental test model for the more accurate analysis, therefore, two cases of FE analyses were carried out with different conditions.

Case 1. Dynamic characteristics of the test model according to the boundary condition change.

Case 2. Dynamic characteristics of the test model according to the size change of the fixture.

Since the test model will be installed at the support structure in an experiment, the effect of the boundary condition between the fixture and the support structure need to be investigated. Therefore, FE analyses with two potential simple boundary conditions as shown in Fig. 2 were carried out in Case 1 analysis. Boundary conditions are as follows:

(a) Fixed condition on the area near bolting holes.
(b) Fixed condition on the contact surface between the fixture and the support structure.

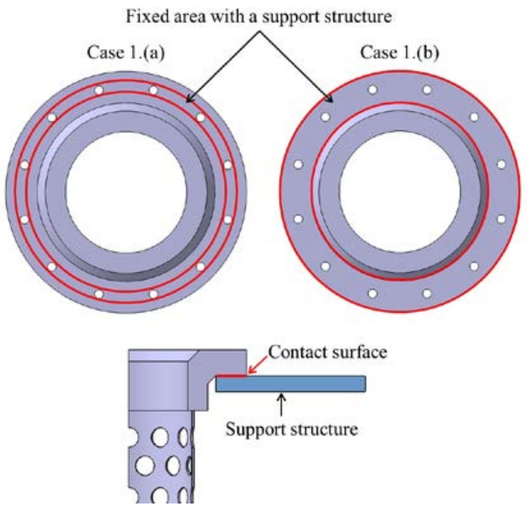

Fig. 2. Area of the boundary condition.

In Case 2 analysis, FE analyses were carried out with two different sizes of fixtures to investigate the effect of the size of the fixture on the dynamic characteristic of the model. Sizes of fixtures considered in Case 2 are as follows:

(a) Twice size of the fixture width compared with Case 1(a).
(b) Three times size of the fixture width compared with Case 1(a).

The fixed boundary condition on the area near bolting holes was used in Case 2.

2.3 Analysis Result

FE analysis results for Case 1 and Case 2 are listed in Table II. For comparison, the natural frequencies and mode shapes of a perforated cylindrical structure without the fixture were additionally investigated and results are shown in Table II and Fig. 3, respectively. The 1st mode shows bending deformation while the 2nd mode shows shell deformation. From the analysis result, one could found that because the mode shapes were almost the same for all Cases, thus natural frequencies were mainly discussed here.

In Case 1, natural frequencies are reduced compared with those of a perforated cylindrical structure without the fixture; 1.8% decrement for the first natural frequency and 1.1% decrement for the second natural frequency in Case 1(a). But the smaller decrement of the natural frequency was observed in Case 1(b). This is because the FE model in Case 1(b) has higher stiffness caused by the boundary condition than that of the FE model in Case 1(a).

In Case 2, the size increment of the fixture increases natural frequencies of the model; 0.6% increment in Case 2(a) and 0.7% increment in Case 2(b), compared with the first natural frequency in Case 1(a). However, the rate of increment is low because the mass is also increased although the stiffness for bending becomes higher.

Table II: Result of the natural frequencies

		Natural frequency (Hz)	
		1^{st} mode	2^{nd} mode
Perforated Cylindrical Structure		132.21	295.94
Case 1	(a)	129.77	294.45
	(b)	130.70	294.65
Case 2	(a)	130.54	294.70
	(b)	130.67	294.71

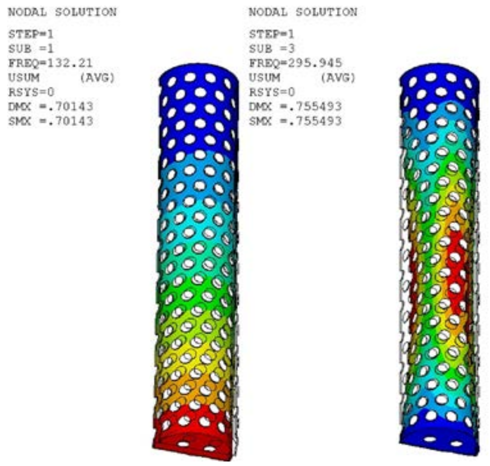

Fig. 3. (a) 1st mode shape and (b) 2nd mode shape of a perforated cylindrical structure.

3. Conclusions and Discussion

In this study, FE analyses of a perforated cylindrical structure with a fixture were conducted to investigate effects of the boundary condition and size of the fixture on the dynamic characteristics of the test model. From FE analysis results, it was evaluated that the increments of fixed area and size of the fixture increase the natural frequency. By employing the proper experimental test model considering these analysis results, therefore, one can expect that the more accurate dynamic characteristic test will be possible.

Acknowledgement

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