Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Natural Frequency Characteristics of a Cylindrical Structure According to the Porosity and Fluid Level

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1. Introduction

The Upper Internal Structure (UIS) in a Sodium-cooled Fast Reactor (SFR) contains several important components such as control rod shroud tubes and instruments guidelines [1, 2]. Therefore, the dynamic characteristic analysis of the UIS is one of important issues for the safety of the SFR and it must be contemplated in the design stage. Moreover, most part of the UIS is submerged in liquid sodium during operation, which may affect the dynamic characteristics of the UIS, the effect of the surrounding fluid must therefore also be considered.

In this study, Finite Element (FE) analysis of a cylindrical structure was performed to investigate the effects of the fluid level and the porosity of the structure on its natural frequency. In the analysis, four test models having different porosities of 0%, 10%, 30% and 50% were considered and the fluid level was varied from 0% to 100% with an increment of 20%. For the analysis, a commercial FE software ANSYS [3] was used and the natural frequencies of 1st mode for four analysis models according to the fluid level were analyzed.

2. Finite Element analysis

2.1 Analysis Model

The geometries of the cylindrical structure are shown in Fig. 1. The porosity of the structure was determined by increasing the diameters of the flow holes that are located at the same positions for all test structures as listed in Table I. In addition, four test structures have the same lumped mass whose height is 100 mm at their bottoms. While Structure A has only a 10 mm hole on the center of the lumped mass, other structures have additional 216 flow holes; 18 rows of flow holes with an interval of 38 mm in the vertical direction and 24 columns of flow holes with an interval of 15° in the circumferential direction. The distances from the bottom of the structure to centers of first flow holes in the first and second columns are 127 mm and 165 mm, respectively [4]. The outer diameter, thickness and height of the cylindrical structure are 165.2 mm, 2.8 mm and 800 mm, respectively.

Figure 2 shows the FE analysis models. It consists of a cylindrical structure, a water tank and the fluid (water). The inner diameter is 300 mm. In this analysis, the fluid level was varied from the bottom to the top of the cylindrical structure with an increment of 160 mm. The material properties used for FE analysis are shown in Table II.

Table I: Diameter of flow hole according to the porosity

	Structure A	Structure B	Structure C	Structure D
Porosity (%)	0	10	30	50
Diameter (mm)	0	14.6	25.1	32.4

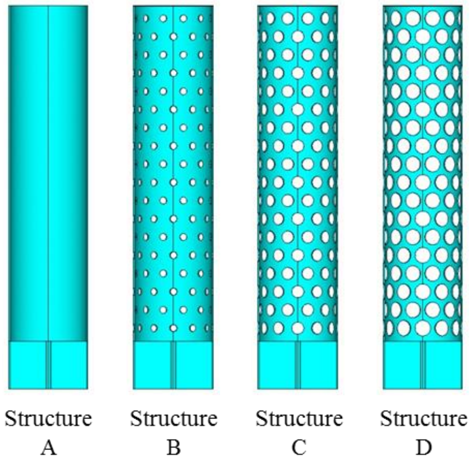

Fig. 1. Geometry of cylindrical structure according to porosity

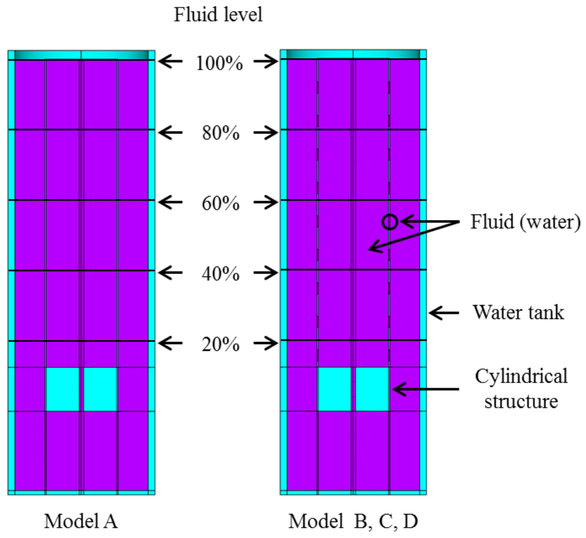

Fig. 2. FE analysis model of fluid level 100%

Table II: Material properties

Material	Solid	Fluid
Young’s modulus (GPa)	195	-
Poisson’s ratio	0.29	-
Density (kg/m^3)	7861.9	999
Sonic velocity (m/s)	-	1481
Dynamic viscosity (m^2/s)	-	1.12e-3

Two element types were used for the analysis model; SOLID185 for the cylindrical structure and the water tank, and FLUID30 for the fluid. In the meshing process of the analysis model, Model B, Model C and Model D were meshed by the combination of hexahedral and tetrahedral elements because of its complexity on the interface between the fluid and flow holes, whereas only the hexahedral element was used for Model A as shown in Fig. 3. In addition, the fixed boundary conditions were applied to the water tank outer surface and the top of the cylindrical structure to investigate the effect of only the fluid on the cylindrical structure.

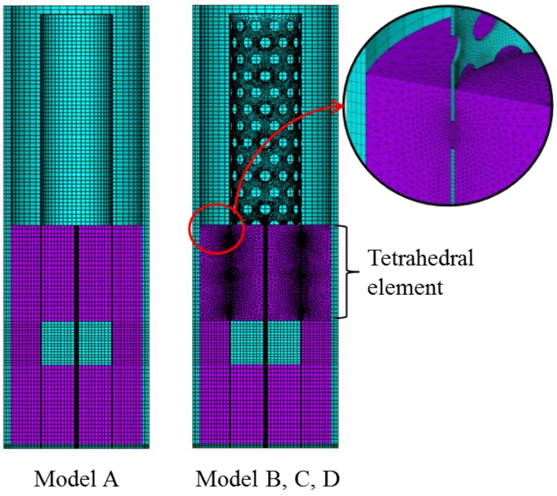

Fig. 3. Mesh of FE analysis model

2.2 Analysis Result

Figure 4 shows the calculated first natural frequencies of Model A, Model B, Model C and Model D when the fluid level is 0%. From the figure, one can see that the natural frequency decreases as the porosity increases unlike the general case that the natural frequency increases as the mass decreases. This is because the existence and size of the flow hole also affects the stiffness of the structure. From this result, therefore, one can conclude that the decrement of the stiffness of the structure due to flow holes is larger than that of the mass. The 1st mode shape of fluid level 0% is shown in Fig. 5.

The natural frequency variations of analysis models according to the fluid level are shown in Fig. 6. From the results, one can see that the natural frequency decreases as the fluid level increases. However, one can also see that the effect of the fluid level on the natural frequency decreases as the porosity increases and the natural frequency barely varies after the certain fluid level; fluid level of 60% for Model A, 40% for Model B and 20% for Model C and Model D.

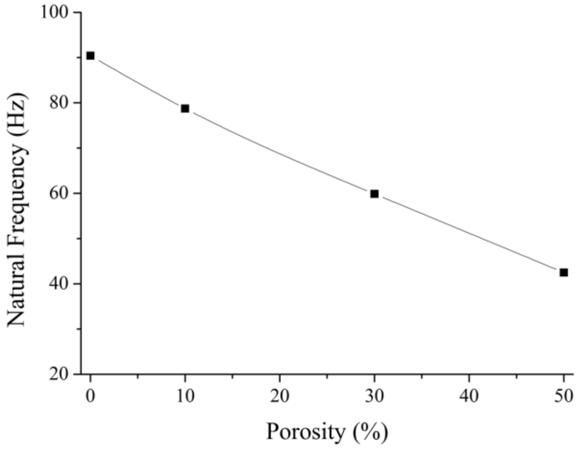

Fig. 4. First natural frequencies of analysis models with the fluid level of 0%

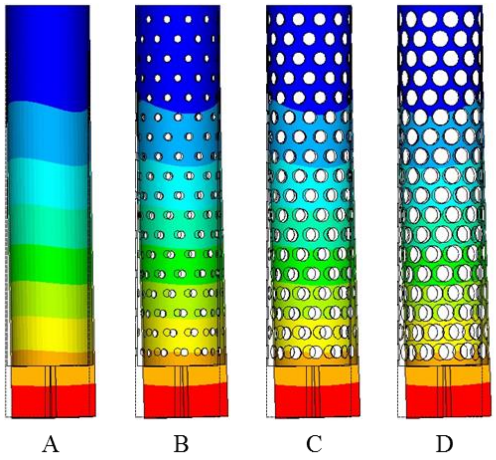

Fig. 5. 1st mode shape of fluid level 0%

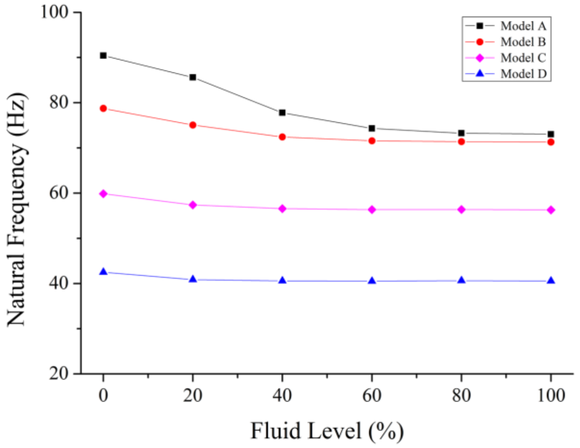

Fig. 6. First natural frequency variations of analysis models according to the fluid level

3. Conclusions

In this study, the FE analysis was conducted to investigate the natural frequency characteristics of a cylindrical structure according to its porosity and the fluid level. Four cylindrical structures having different porosities and six different fluid levels were considered. The analysis results showed that the porosity affects the stiffness of the structure more than the mass; the natural frequency decreases as the porosity of the cylindrical structure increases. In addition, the natural frequency decreases as the fluid level increases. But the effect of the fluid level on the natural frequency decreases as the porosity increases and the natural frequency barely varies after the certain fluid level.

Acknowledgement

This study was supported by the National Research Foundation grant funded by the Korea government (Ministry of Science, ICT and Future Planning).

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