Modal Analysis for a Porous Cylindrical Structure of PGSFR

Kang Soo Kim [a*], Sung Kyun Kim [a], Keun Bae Park [a]
[a]*Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon*
[*]*Corresponding author: kskim5@kaeri.re.kr*

1. Introduction

The Upper Internal Structure (UIS) for the Prototype Gen IV Sodium Fast Reactor (PGSFR) is attached to the rotatable plug of the reactor vessel head and cantilevered downward into the reactor hot pool. UIS is a porous cylindrical structure with many holes at the lateral and bottom side. Up-stream coolant passes through these holes. Also, UIS contains 2 porous horizontal structural plates and 9 CRDM (Control Rod Drive Mechanism), 6 thermocouple conduits and 7 sensor guide pipes.

In this paper, 3D full model and the reduced seismic model for the UIS was built up respectively. The reduced seismic model will be used for the seismic analysis of the overall NSSS structures. The modal analysis results for 3D full model and the reduced seismic model in the air were compared and the feasibility for the reduced seismic model was confirmed. Also, the natural frequencies for the UIS in the fluid (liquid sodium) were calculated utilizing the reduced seismic model.

2. Methods and Results

2.1 FEM Model

The UIS is made of SS316 stainless steel. 3D full model using the ANSYS Code [1] is shown in Fig. 1. Element SOLID 185 and BEAM 188 are used for the modeling. The dimensions of the UIS are as follows.

- Cylinder Diameter of UIS : 1.65 m
- Height of UIS : 8.944 m

6 DOF fixed boundary condition was applied at the area welded with the reactor vessel head..

The reduced seismic model for the UIS using the ANSYS Code is shown in Fig. 2. Element MASS 21 and BEAM 4 are used for the modeling. 6 DOF fixed boundary condition was applied at the area welded with the reactor vessel head.

UIS is divided to 4 parts considering the horizontal lower plate, horizontal middle plate and horizontal upper plate. The masses are distributed at the place where 3 horizontal lower plates are located and without flow holes. From the top, L1, L2, L3 and L4 is 2.650 m, 1.486m, 3.863m and 1.165m respectively.

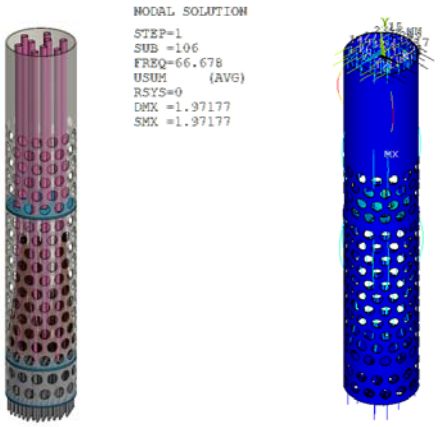

Fig. 1 ANSYS model of 3D full model

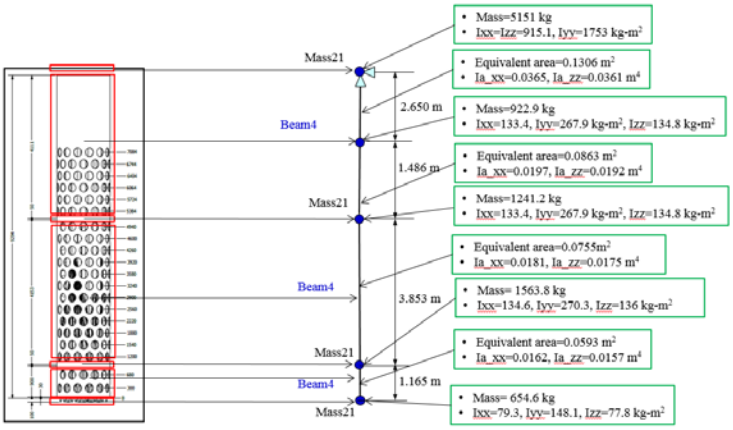

Fig. 2 ANSYS model of the reduced seismic model

The equivalent area and the area moment of inertia for the beam element are calculated at 3D modeling of INVENTOR. The mass and the mass moment of inertia for the mass element are also calculated at 3D modeling of INVENTOR as shown in Figure 3.

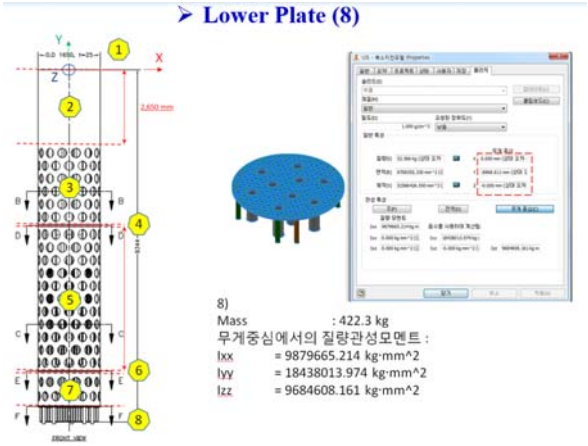

Fig. 3 Calculation of mass and mass moment of inertia

2.2 Material Properties

The material properties are presented in Table 1 [2].

Table 1 Material Properties of UIS

Material Properties	SS316
Modulus of Elasticity(N/m^2)	189E9
Poisson's Ratio	0.3
Density(kg/m^3)	8000

2.3 Modal Analysis Results

The modal analysis results for 3D full model and the reduced seismic model are shown in Fig. 4 and Fig 5 respectively.

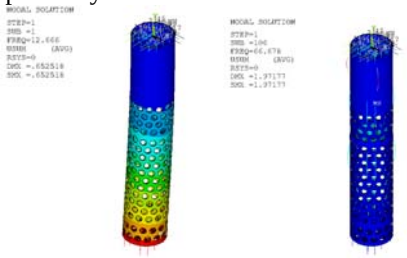

Fig. 4 1st and 2nd mode for 3D full model

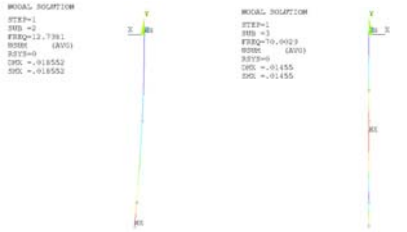

Fig. 5 1st and 2nd mode for the reduced seismic model

The modal analysis results of 3D full model and the reduced seismic model are presented in Table 2.

Table 2 Modal Analysis Results of 3D full model and the reduced seismic model.

	1st Mode (Hz)	2nd Mode(Hz)
3D full model	12.666	66.678
Reduced Seismic Model	12.798	70.003

To calculate the natural frequencies of the UIS in the fluid (liquid sodium), the added mass was calculated by FAMD analysis. The calculation position and porosity are shown in Fig. 6. Added masses were distributed at each mass point of the reduced seismic model. The natural frequencies of the UIS in fluid were 9.0048 Hz (1st) and 55.360 Hz (2nd) respectively.

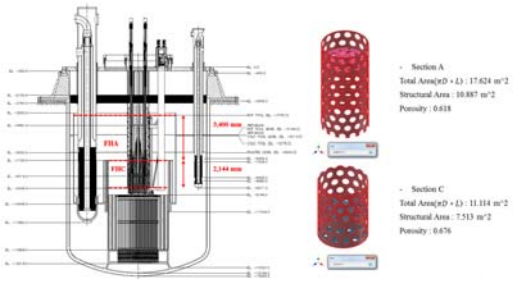

Fig. 6 Calculation position and porosity for added mass

3. Conclusions

The modal analysis results of 3D full model are compared with those of the reduced seismic model for calculating the natural frequencies for the UIS in the air. The two results show good agreement. Also, the added mass is calculated to determine the natural frequencies of the UIS in the liquid sodium. For the reduced seismic model, 1st mode of the UIS in the liquid sodium is 9.0048 Hz.

Acknowledgements

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REFERENCES

[1] ANSYS Users manual, Release 15.0, ANSYS Inc.

[2]] KS Kim, SK Kim, KB Park, Preliminary Thermal Stress Analysis for a Fuel Transfer Cask of PGSFR, Transactions of the Korean Nuclear Society Spring, Meeting, 2017