Modal Characteristics of Flow Skirt using Equivalent Young's Modulus

Myung Jo Jhung* and Yong Beum Kim
Korea Institute of Nuclear Safety, 19 Guseong-dong, Yuseong-gu, Daejeon
**mjj@kins.re.kr*

1. Introduction

Many innovative design features for SMART are employed in the reactor vessel internals and one of them is flow skirt for distributing flow uniformly, restraining horizontally the lower part of core support barrel (CSB), and supporting core if the fuel assembly drops into the reactor vessel lower head due to CSB failure. For this kind of new design, it is necessary to investigate comprehensive vibration characteristics, which is being performed analytically and experimentally by the designer as a part of preparing a document for licensing purpose.

Therefore in this study, investigated are modal characteristics of flow skirt using the finite element analysis. The effect of thickness of the lowest shell, three rings attached to the flow skirt, and holes are investigated on the vibration characteristics. In addition, the fluid effect is also addressed because the flow skirt is submerged in the fluid.

2. Analysis

Several finite element analyses using a commercial computer code ANSYS 12.0 [1] are performed to get the natural frequencies. The Block Lanczos method is used for the eigenvalue and eigenvector extractions of the finite element model, which is available for large symmetric eigenvalue problem. Typically this solver is applicable to the type of problems solved using the subspace eigenvalue method, however, at a faster convergence rate, and is very useful to find all exact symmetric modes necessary to define the dynamic characteristics of the shell. In this case several sloshing modes of a fluid appear at the same time and therefore they should be excluded for the shell modes only.

The effective elastic constants for the perforated shell are suggested by performing several finite element analyses with respect to the ligament efficiencies [2]. Because the elastic constant is proportional to the square of the natural frequency, multipliers of Young's modulus of solid shell to match natural frequencies of perforated shell with original properties using the relations between natural frequency and Young's modulus are found and effective elastic constant for each ligament efficiency is averaged for all modes, generating the effective elastic constants for modal characteristics of the perforated shell with a triangular penetration pattern as;

$$\frac{E^*}{E} = 0.1610 + 1.7421\eta - 2.0365\eta^2 + 2.2733\eta^3 - 1.1471\eta^4$$

where E, E^* and η are original Young's modulus, effective one, and the ligament efficiency, respectively. The effective elastic constant defined above should be limited only for $0.5 \le \eta \le 0.8$ for the frequency errors of the perforated shell to be within 10% because it was obtained by averaging effective elastic constants according to the ligament efficiency [2].

3. Results and Discussion

Natural frequencies of flow skirt are obtained with respect to various conditions and they are categorized as axial and circumferential modes, where the symbol m represents the number of axial mode and the symbol n means the number of circumferential mode. Two different natural frequencies for certain modes are obtained because the fixed boundary conditions at the bottom of the shell are not fully symmetric with every 30 degrees fixed in the circumferential direction. The natural frequency variations are shown in Figs. 1 and 2 for a flow skirt with holes without water and one without holes with or without water, respectively.

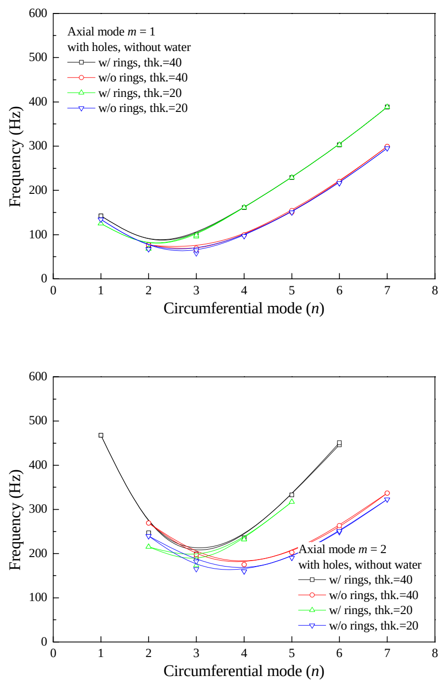

Fig. 1. Natural frequencies of flow skirt with holes without water

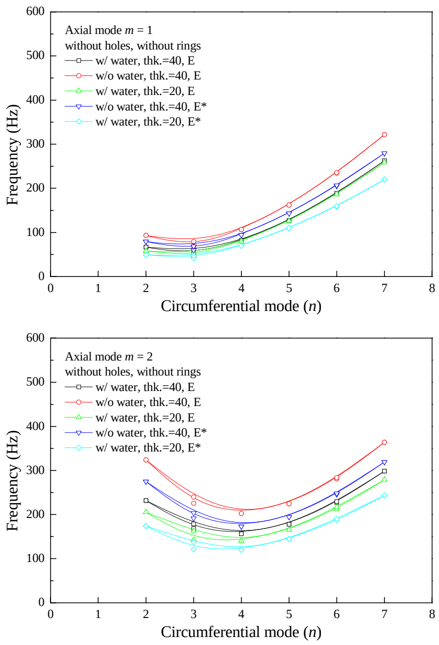

Fig. 2. Natural frequencies of flow skirt without holes with or without water

Several sensitivity runs are performed for holes, water, rings and thickness of the lowest shell, and their results are compared each other. Because a flow skirt consists of perforated shell with many holes, hole effect is investigated. Natural frequency comparisons between with- and without-holes are shown in Fig. 3 and their normalized values of with-holes to without-holes are shown in Fig. 4. For the lower axial modes the hole effects are almost negligible but as the axial mode increases the effect becomes significant. By including holes in the flow skirt model, the natural frequencies decrease about 12% for the first three axial modes.

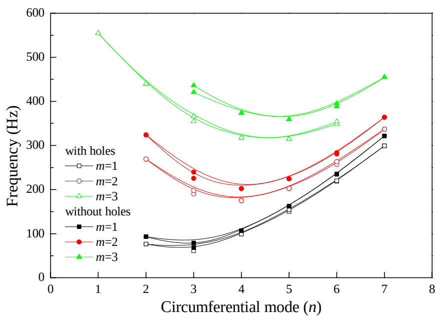

Fig. 3. Effect of holes on the natural frequencies

A flow skirt has three inner rings attached in it and these will stiffen the structure and will increase the natural frequencies as shown in Fig. 5. For the lower circumferential modes the natural frequencies are almost the same but with the increasing circumferential modes the natural frequencies increase too much, which should not be neglected. To increase the natural frequency, it was found to be a good design to attach the inner rings to the shell type of structure.

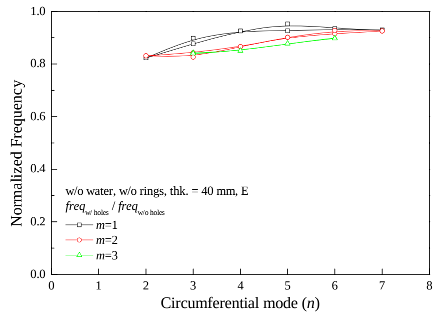

Fig. 4. Normalized natural frequencies of flow skirt considering hole effect

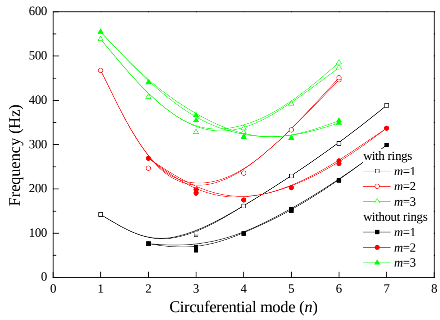

Fig. 5. Effect of rings on the natural frequencies

4. Conclusions

Modal characteristics of the flow skirt for SMART are investigated in this study. Various sensitivity studies are performed to get the effect of thickness of the lowest shell, three rings attached to the flow skirt, holes and water on the vibration characteristics, generating the following conclusions:

- The first natural frequency of the flow skirt is 68 Hz in air and 41 Hz in water.
- The three rings attached inside the flow skirt increase natural frequencies too much for the higher circumferential modes, which should not be neglected.
- By including hole effect, the natural frequencies are lowered to about 89% of the without-hole natural frequencies.
- By including fluid effect, the natural frequencies are lowered to about 75% of the in-air natural frequencies.

REFERENCES

[1] ANSYS, Inc., Theory Reference for ANSYS and ANSYS Workbench Release 12.0, Canonsburg, PA (2009).

[2] Jhung, M.J., Yu, S.O., "Study on modal characteristics of perforated shell using effective Young's modulus," Nuclear Engineering and Design, Vol.241, pp.2026-2033 (2011).