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Modal Analysis of CSB and RV assembly for Normal Contact

Niniek Ramayani Yasintha [a], Namgung Ihn [a*],
KEPCO International Nuclear Graduate School (KINGS)
Ulju-gun, Ulsan Korea 45014
[*]*Corresponding author: inamgung@kings.ac.kr*

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1. Introduction

Modal analysis is an essential instrument in understanding the dynamic performance of complex mechanical systems, offering valuable insights into their inherent frequencies, modal patterns, and seismic attributes [1]. In the field of nuclear engineering, analyzing the structural dynamics of CSB and RV assembly is significant to safeguard the safety and structural integrity of nuclear power plants [2]. The CSB, is an integral component of the reactor vessel. The CSB provides structural support and alignment for the reactor core, it helps to maintain the position and stability of the reactor core components during normal operation and under various loading conditions, such as thermal expansion, and seismic events. [3-4]. The RV encloses the reactor core and contains the nuclear fuel, coolant, and other internal reactor components. The RV is designed to withstand elevated pressures, temperatures, and to prevent the escape of radioactive materials release into the surroundings [5]. This research is centered on conducting modal analysis of the CSB and RV assembly under normal contact conditions, aiming to assess its seismic resistance during normal operations.

2. Methods and Results

In this section the modal analysis of CSB and RV assembly for various scenarios are described, followed by a comparative analysis of the results obtained from these scenarios.

2.1. Normal Contact between CSB and RV

There is an interface between the CSB and RV, this interface is crucial for maintaining the overall structural integrity and safety of the nuclear reactor. This study focuses on the normal contact between the outlet of the CSB and the hot-leg nozzle of the RV. Scenarios that should be considered are those that present a gap between the RV and the CSB and others that involve direct contact between the CSB and the RV. Figure 1. Shows the interface between CSB and RV.

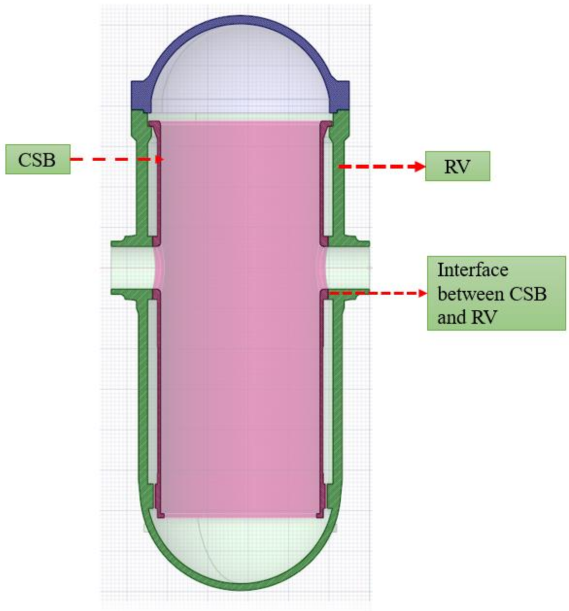


Fig. 1. Interface between CSB and RV

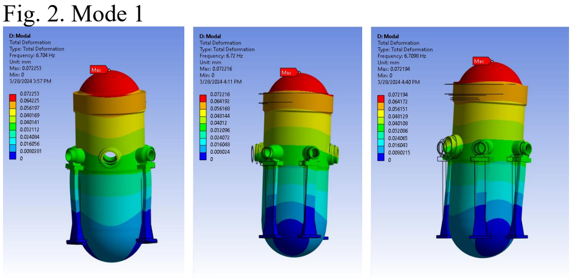
2.2 Modal Analysis of CSB and RV

Modal analysis of the CSB and RV involves studying the dynamic behavior of these components within a nuclear reactor system. This analysis aims to determine the natural frequencies, mode shapes, and damping characteristics of the CSB and RV. By conducting modal analysis, we can assess the structural integrity and performance of the CSB and RV, helping to ensure the safe and efficient operation of nuclear reactors. This information is crucial for understanding how the CSB and RV respond to external forces, such as seismic events or thermal fluctuations, and for optimizing their design to enhance reliability and safety.

2.3. Results

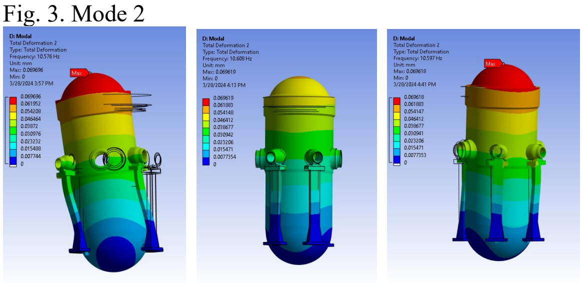
Results from the CSB and RV modal analysis for normal contact events yielded several significant findings. First, this study considers various scenarios for the interface between CSB and RV, including gaps between them, direct contact, and overlap. The importance of a thorough understanding of these scenarios cannot be emphasized enough as they play a critical role in maintaining the structural integrity and overall safety of a nuclear reactor. In addition, this analysis also reveals the dynamic behavior of CSB and RV in nuclear reactor systems, by determining the natural frequencies, mode shapes, and damping characteristics of these components. The results of the modal analysis are also presented in figures 2 through 11 depicting the different vibration modes for the CSB and RV assemblies, providing valuable insight into the structural response of the components. The modal analysis allows us to determine the natural frequencies of CSB and RV. This information is important in understanding how the structure will respond to possible seismic vibrations. By analyzing the vibration modes of the CSB and RV, it can be understood how the structure will move or vibrate when seismic shocks occur. This helps in evaluating the structural capability of these components to withstand seismic loads. By understanding the dynamic characteristics of CSBs and RVs through modal analysis, design improvements can be made to increase resistance to seismic shocks. This contributes to increasing the operational safety of nuclear reactors in the face of potential seismic risks.

Fig. 2. Mode 1



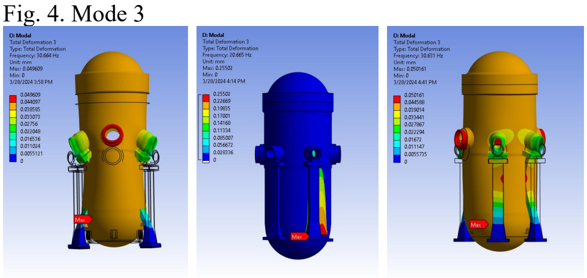
(a). With Gap (b). Contact (c). Overlap

Fig. 3. Mode 2



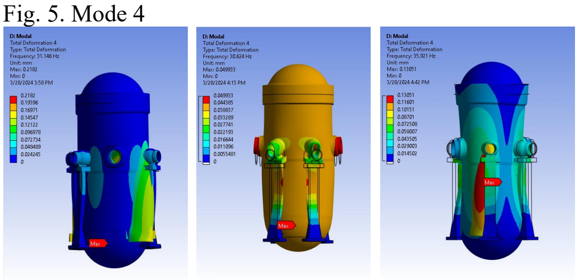
(a). With Gap (b). Contact (c). Overlap

Fig. 4. Mode 3



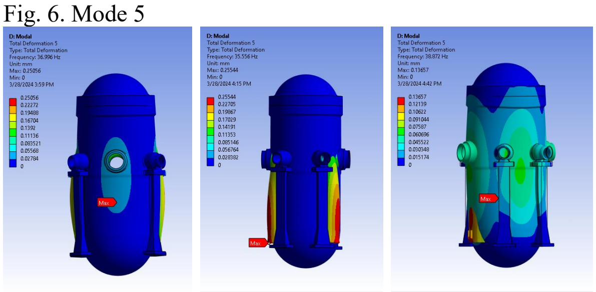
(a). With Gap (b). Contact (c). Overlap

Fig. 5. Mode 4



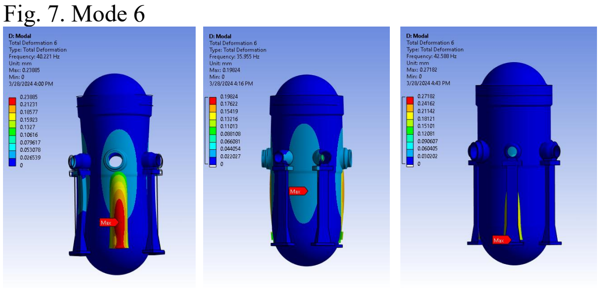
(a). With Gap (b). Contact (c). Overlap

Fig. 6. Mode 5



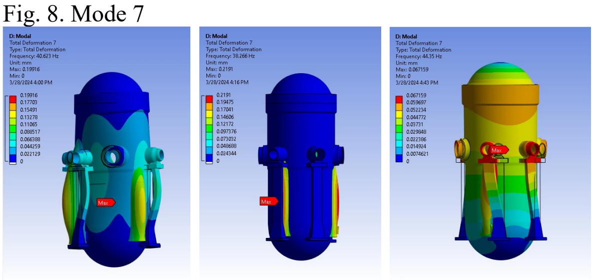
(a). With Gap (b). Contact (c). Overlap

Fig. 7. Mode 6



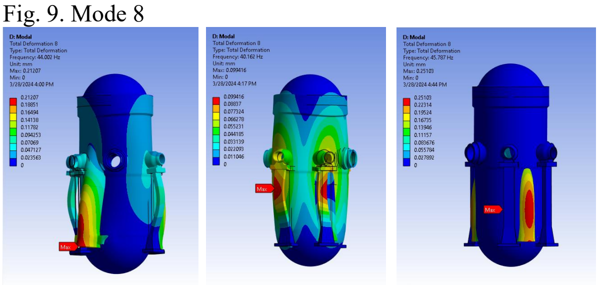
(a). With Gap (b). Contact (c). Overlap

Fig. 8. Mode 7



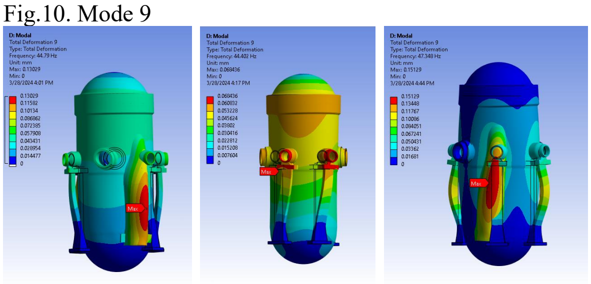
(a). With Gap (b). Contact (c). Overlap

Fig. 9. Mode 8



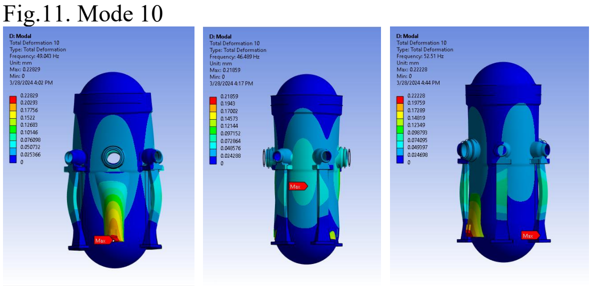
(a). With Gap (b). Contact (c). Overlap

Fig.10. Mode 9



(a). With Gap (b). Contact (c). Overlap

Fig.11. Mode 10



(a). With Gap (b). Contact (c). Overlap

Table 1. Result of Modal Frequency

Mode	With Gap	Contact	Overlap
1	6.704	6.72	6.7098
2	10.576	10.608	10.597
3	30.664	20.665	30.631
4	31.146	30.624	35.921
5	36.996	35.556	38.872
6	40.221	35.955	42.588
7	40.623	38.266	44.35
8	44.002	40.162	45.787
9	44.79	44.402	47.348
10	49.043	46.489	52.51

3. Conclusions

Based on the results from Table 1, the best conditions that can be used are normal contact conditions between the Core Support Barrel (CSB) and the Reactor Vessel (RV). Normal contacts have the lowest modal frequency. This indicates that normal contacts have a more stable dynamic response and are closer to ideal conditions in the CSB and RV systems.

By using normal contact conditions, CSB and RV systems can be expected to have optimal dynamic characteristics. In this context, a low modal frequency indicates that the mode has lower vibration energy, which can reduce the vibration amplitude and increase the structural stability of the system. Thus, normal contact conditions can help increase resistance to seismic loads and maintain structural integrity during normal operations in nuclear reactors.

In addition, selecting normal contact conditions can also provide advantages in terms of design efficiency. By considering low modal frequencies, the structural design can be optimized to reduce undesirable vibration responses and strengthen the system's ability to withstand external forces, such as seismic loads. This can contribute to improving the operational reliability and safety of nuclear reactors.

Thus, based on the modal frequency analysis of the contact conditions between CSB and RV, the best condition that can be used is the normal contact condition.

4. Acknowledgement

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