Seismic Response Analysis of Assembled Reactor Vessel Internals

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1. Introduction

RVIs (Reactor Vessel Internals) perform important safe-related functions such as upholding the nuclear fuel assembly as well as providing the coolant passage of the reactor core and supporting the control rod drive mechanism. Therefore, the components including RVIs have to be designed and constructed taking into account the structural integrity under various accident scenarios. Recently, the seismic loading which may lead to significant functional damage in reactor coolant boundary has been attentioned after the Fukushima accident. The reliable seismic analysis is essentially demanded to maintain the safe-related functions of RVIs. In this study, a modal analysis was performed based on the previous researches[1] to examine values of frequencies, mode shapes and participation factors. Subsequently, the structural integrity respecting to the earthquake was evaluated through a response spectrum analysis by using the output variables of modal analysis.

2. Analysis Procedure

Fig. 1 shows the flowchart of response spectrum analysis according to the ASME code[2]. The results of modal analysis (frequency, mode shape and participation factor) were applied as input parameters of the response spectrum analysis with DRS (Design Response Spectrum) data[3] to obtain the stress values.

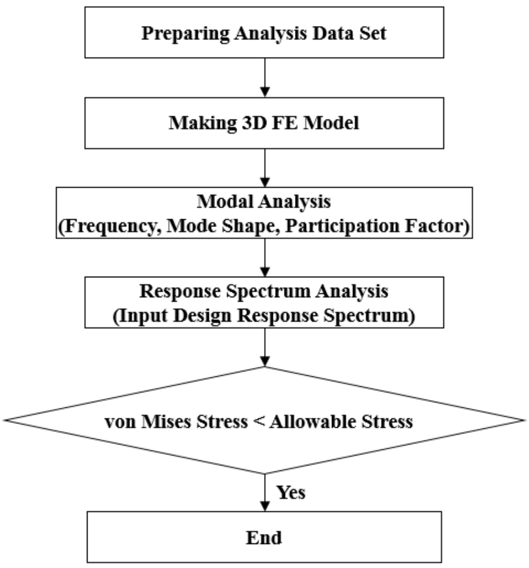


Fig. 1 Flowchart of response spectrum analysis

3. Analysis Methods and Results

3.1 Analysis Model

Four major subcomponents with regard to the assembled condition and the structural importance were selected. Fig. 2 represents 3-D numerical models composed of CSB (Core Support Barrel), UGS (Upper Guide Structure), LSS (Lower Support Structure), CSA (Core Shroud Assembly). The detailed model was developed based on a design documents[4,5] of a typical nuclear power plant and the response spectrum analysis of RVIs was performed by using commercial software, ANSYS Workbench[6]. Materials considered in this study for seismic response analysis are SA508 and austenitic stainless steels. The relevant material properties are summarized in Table I.

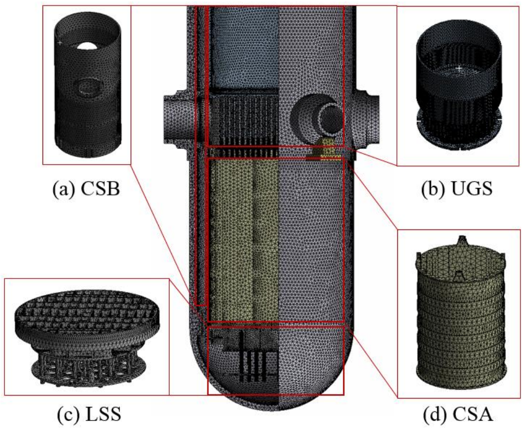


Fig. 2 Numerical model of assembled RVIs

Table I: Material properties

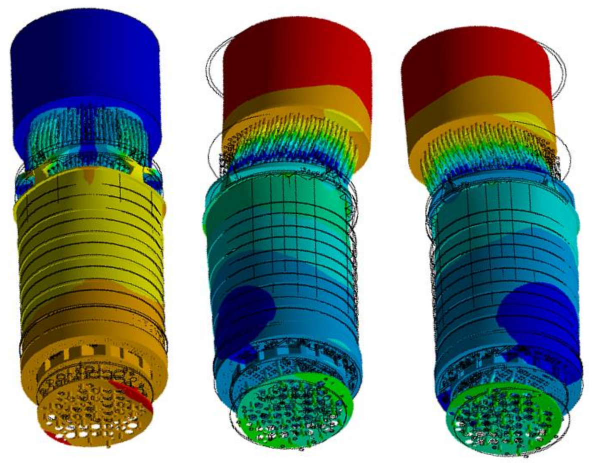
RPV	Young's modulus	200GPa
	Poisson's ratio	0.29
	Density	8,000Kg/m^3
RVI	Young's modulus	176GPa
	Poisson's ratio	0.31
	Density	7,750Kg/m^3

3.2 Modal Analysis

Block Lanczos method was employed in the modal analysis to determine the values of frequencies, mode shapes and participation factors. The first mode shape of RVIs occurred at 9.812Hz and the corresponding effective mass ratios were summarized in Table II, respectively. Fig. 3 represents typical mode shapes of the assembled RVIs at the maximum effective mass.

Table II: Result of modal analysis

Mode	Frequency (Hz)	X	Y	Z
		Effective mass ratio		
1	9.81	0.90e-07	0.14e+00	0.27e-02
8	42.32	0.17e+00	0.34e-07	0.16e-07
9	61.38	0.10e-06	0.41e+00	0.21e-03
13	73.34	0.34e-07	0.19e-06	0.41e+00



(a) 8th mode shape (42.32Hz) (b) 9th mode shape (61.38Hz) (c) 13th mode shape (73.34Hz)

Fig. 3 Typical mode shapes of assembled RVIs

3.3 Response Spectrum Analysis

The total response was calculated through the square root of the sum of the squares method for all the individual modal response. Subsequently, the DRS was applied at the cold leg nozzle of RPV as shown in Fig. 4, for the response spectrum analysis, in which 4% of damping value was considered based on the previous research[7]. Fig. 5 represents resulting stress contour. The maximum von Mises stress of 287MPa occurred between UGS and CSA, which satisfied the corresponding allowable criterion[8].

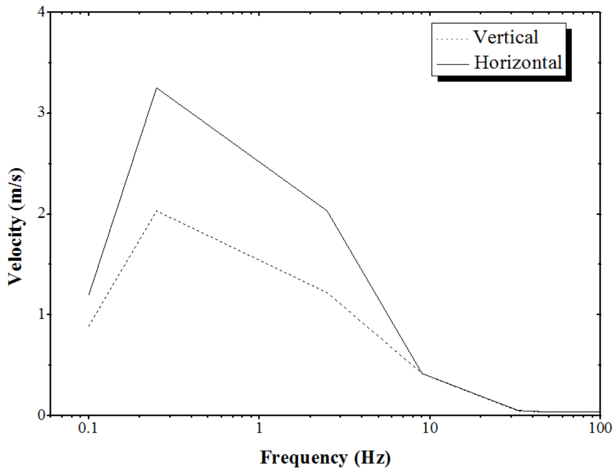


Fig. 4 DRS considering with 4% damping value

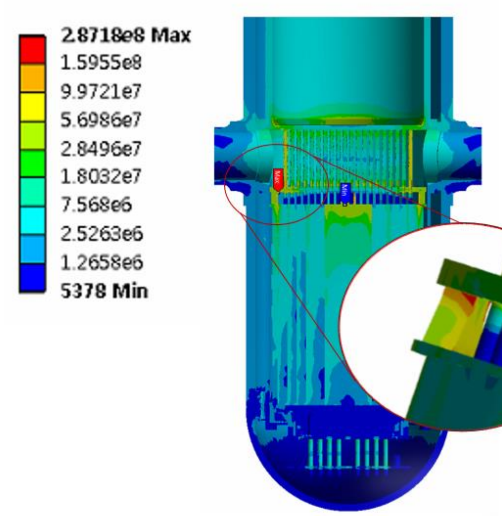


Fig. 5 Stress contour and maximum stress location

4. Conclusions

In this study, the structural integrity of the assembled RVIs was carried out against the seismic event via the modal and response spectrum analyses. Even though 287MPa of the maximum stress value occurred at the connected region between UGS and CSA, which was lower than its allowable value. At present, fluid-structure interaction effects are being examined for further realistic simulation, which will be reported in the near future.

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