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A Seismic Analysis for Reflective Metal Insulation

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1. Introduction

U.S. NRC (Nuclear Regulatory Commission) GSI-191 (Generic Safety Issue-191) is concerned about the head-loss of emergency core cooling pumps caused by calcium silicate insulation debris accumulated on a sump screen when a loss of coolant accident (LOCA) [1, 2]. In order to cope with the concern, many nuclear plants in U. S. have been replacing calcium silicate insulation in containment building with reflective metal insulation (RMI) [3].

In Korea, RMI has been used for only reactor vessels recently constructed, but the RMI was imported. Therefore, we have been developing the domestic design of RMI to supply to nuclear power plants under operation and construction in relation to the GSI-191. This paper covers that the structural integrity of the RMI assembly was evaluated under SSE (safety shutdown earthquake) load.

2. Methodology and model

A RMI is manufactured through several thin stainless steel foils stacked in a stainless steel external sheath. The foils prevent conductive, convective, and radiative heat transfer in the external sheath [4]. The RMI design shall be such that during a SSE load, no piece, part, subassembly or appurtenance can structurally fail and become a missile [5]. Therefore, in order to review the integrity of a RMI assembly installed on components of nuclear power plant under the SSE load, pre-stress, modal, spectrum analyses were performed using ANSYS, a commercial structural analysis code [6].

The analysis model was generated as shown in Fig. 1 to describe the system for seismic test of RMI assembly. The model consists of a cylinder with diameter 1,016 m, wall thickness 0.012 m, height 2.5 m, 18 RMIs, support plate, and 2 support rings. The square support plate of the cylinder is fixed with concrete slab structure and upper and lower support rings are welded with the cylinder. A RMI is vertically bolted with the upper and lower support rings and other RMIs and circumferentially fastened with other RMIs using buckles. The fastening force of a buckle is 138.2 N.

Tetrahedron elements were used for the mesh of the analysis model. The number of node and element were 1,481,184 and 742,757 respectively. Contact surfaces between RMIs and of buckles were set to be frictional condition and the frictional factor of the condition was 0.2. Bolting and welding were assumed to be fixed condition. Block Lanczos method was used for modal analysis and 100 natural frequencies were found. Loads for the spectrum analysis are 3 directional 110 % required response spectrum (RRS) including the SSE response spectrum for pressurizer, reactor vessel, and steam generator in Shin-Kori 3 and 4 as shown in Fig. 2 [7]. The black line of the figure is RRS and the red line is 110 % RRS. The maximum acceleration of the 110 % RRS is 22 g horizontally and 6.6 g vertically.

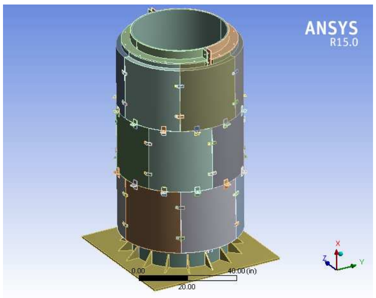
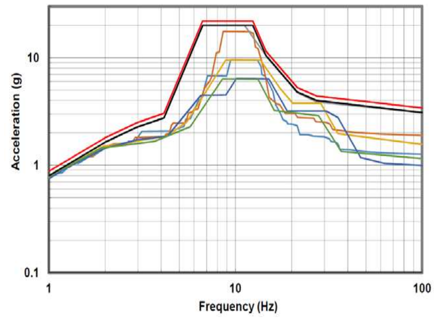
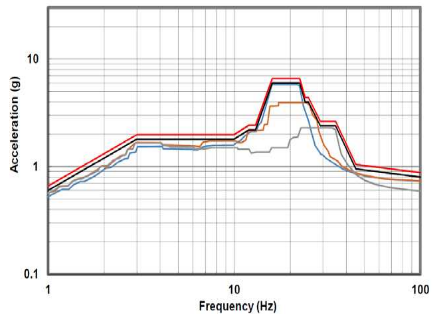


Fig. 1. Analysis model for seismic test system of RMI



(a) Horizontal response spectral



(b) Vertical response spectral

Fig. 2. Response spectrums for spectrum analysis

3. Analysis Results

Structural responses of the test system for the dead weight and the fastening forces of the buckles were calculated through static structural analysis and the location and the value of the maximum von-Mises stress was a buckle and 8.15 MPa and the value is less than the yield stress (248.2 MPa) of the material of the buckle.

Table I shows the natural frequencies of the test system calculated by the modal analysis. The first natural frequency is 105.81 Hz and since this value is rather high, the test system can be judged to show rigid body motion under a SSE load. The first mode of the model is the oval deformation of the upper area. The second mode is the shape that the cylinder bends like a beam.

The von-Mises stress distribution of the test system by the spectrum analysis is presented in Fig. 3. The maximum von-Mises stress, 20.78 MPa, appears at a welding point between the cylinder and a triangular plate which connects the support plate and the cylinder. Fig. 4 indicates the von-Mises stress distribution for all buckles and the maximum and minimum stress among the buckles is 2.75 and 0.54 MPa respectively. Since the maximum stress is very lower than the yield stress of the material of the buckle, the buckle is not damaged from the SSE load.

Table I: Natural frequencies of test system

Mode	Freq. [Hz]	Mode	Freq. [Hz]
1	105.81	6	145.24
2	107.33	7	147.62
3	107.41	8	151.56
4	115.25	9	153.45
5	142.63	10	154.66

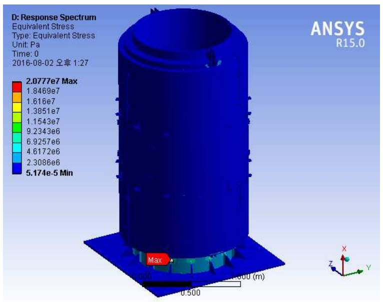


Fig. 3. Equivalent stress distribution of the test system by spectrum analysis

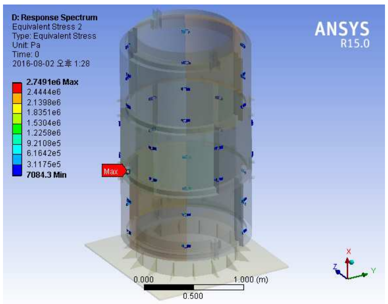


Fig. 4. Equivalent stress distribution of the buckles by spectrum analysis

4. Conclusions

An analysis model was built for the seismic test system of a reflective metal insulation assembly and pre-stress, modal, and spectrum analysis for the model were performed using a commercial structural analysis code, ANSYS. According to the results of the analyses, the buckles fastening the RMIs showed the structural integrity under the required response spectrum containing the safety shutdown earthquake loads applied to main components in containment building. Consequently, since the RMI isn't disassembled under the SSE load, the RMI is judged not to affect safety related components. In the future, we will verify the seismic analysis comparing with test results.

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