Deterministic Hydraulic Load Analysis on Reactor Internals of APR1400

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1. Introduction

The structural integrity of the reactor vessel internals (RVI) of the nuclear power plants that have been constructed should be verified in accordance with the US Nuclear Regulatory Commission Regulatory Guide 1.20 (RG1.20) comprehensive vibration assessment program (CVAP) during preoperational and initial startup testing [1]. The program consists of a vibration and stress analysis, a vibration measurement, an inspection, and an assessment of each program [1]. The vibration and stress analysis program is comprised of a hydraulic load analysis and a structural response analysis. The hydraulic loads include the random hydraulic loads induced by turbulent flow and deterministic hydraulic loads induced by pump pulsation [2,3]. This paper describes a developed full scope 3-D model and the deterministic hydraulic loads for the RVI of the APR1400.

2. Analysis Method and Model

2.1 Deterministic Hydraulic Load Analysis Method

Figure 1 represents the hydraulic load analysis method developed to comply with RG1.20 [4]. The deterministic loads and random loads are assumed to be caused by independent sources. Thus those hydraulic loads can be calculated separately. The deterministic hydraulic loads are due to the pulsations of the reactor coolant pump (RCP). The pulsations propagate through the RVI as acoustic waves, independent of fluid velocity. The pulsations also occur at multiples of the pump rotor frequency (20 Hz) and blade passing frequency (120 Hz). In OPR1000 plants, mathematical equations and Palo Verde Unit 1(PV#1) CVAP data have been used to predict the deterministic hydraulic loads [2]. In this study, the 3-D model for the RVI of the APR1400 was developed and the Fluid30 element of ANSYS 13.0 was used to calculate the deterministic loads.

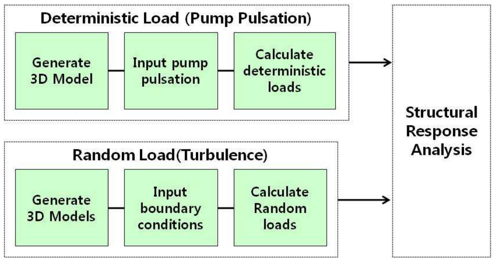

Fig. 1. Hydraulic Load Analysis Method

2.2 Reactor Vessel Internals Model

The modeling scope included all the fluid space inside the reactor vessel as shown in Figure 2. The number of the mesh of the RVI model was approximately 3.5 million and tetrahedral mesh was used. The boundary condition was four RCPs in operation and the temperature and pressure of water was 550 ˚F and 2250 psi respectively. Inlet boundaries of the reactor vessel were set by the pressure pulsations of the RCPs as listed in Table 1 [5].

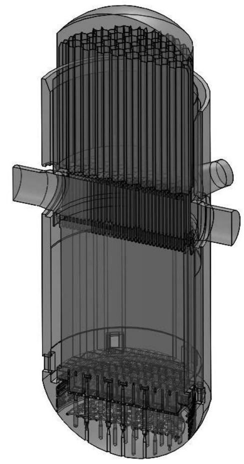

Fig. 2. 3-D model of RVI

Table 1. Pressure Induced by one RCP in Inlet Nozzle

Frequency (Hz)	Pressure (psi)
20	0.19
40	0.05
120	0.08
240	0.50
360	0.08
480	0.42

3. Analysis Results

The deterministic load distributions for the pump pulsations at 20 Hz and 480 Hz are shown in Figures 3 and 4 respectively. The differences between the distributions were caused by the frequencies of the pump pulsation and the responses of the fluid. As shown in Figure 5, the RMS pressures estimated for the 3-D model are compared with the loads analyzed and measured on the support guide structure support plate in the OPR1000 CVAP. The tendency of the deterministic loads of the APR1400 is very similar to that of the

OPR1000, since the valid prototype of both APR1400 and OPR1000 is the PV#1 and the APR1400 has the structural similarity to the OPR1000 and PV#1 except for the upper guide structure assembly. The deterministic pressures of the APR1400 also are closer values to the measured values of the OPR1000 than the analyzed results of the OPR1000.

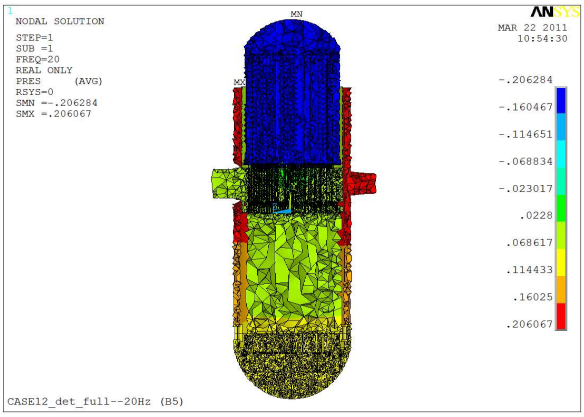

Fig. 3. Distribution of the deterministic loads for the pump pulsation at 20Hz

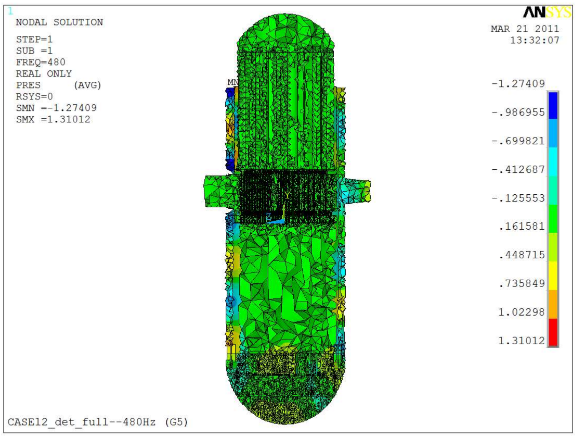

Fig. 4. Distribution of the deterministic loads for the pump pulsation at 480Hz

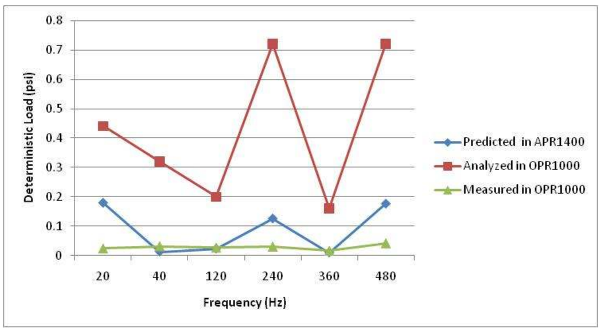

Fig. 5. RMS Pressures on the upper guide structure support plate

4. Conclusions

An acoustic analysis to estimate the deterministic hydraulic loads for the APR1400 was performed using a 3-D model and the ANSYS. The 3-D model was developed to include all the fluid region of the reactor vessel. This method provided more realistic results than the analysis method of the OPR1000. In future studies, the random hydraulic loads and structural responses will be predicted and the structural integrity for the RVI of APR1400 will be verified by comparing the structural responses with the results of a vibration measurement program.

REFERENCES

[1] U.S. Nuclear Regulatory Commission Regulatory Guide 1.20, "Comprehensive Vibration Assessment Program for Reactor Internals during Preoperational and Initial Startup Testing", Revision 3, March 2007.

[2] KEPCO, 10487-ME-TE-240-03, "A Comprehensive Vibration Assessment Program for Yonggwang Nuclear Generating Station UNIT 4", Rev. 0, August 1995.

[3] KEPRI, TM.99NJ13.P2000.243, "Report on the Observation and Synthesis about CVAP in KNGR RVI", June 2000.

[4] Y. S. Kim, K. H. Kim, and J. H. Lee, Hydraulic Load Analysis for RVI Comprehensive Vibration Assessment Program, Transactions of the Korean Nuclear Society Autumn Meeting, p.449-450, Oct.21-22, 2010.

[5] Combustion Engineering, Inc., "Comprehensive Vibration Assessment Program for the Prototype System 80 Reactor Internals (Palo Verde Nuclear Generating Station UNIT 1)", 1984.

[6] J. Y. Gu, K. H. Kim, and Y. S. Kim, Development and Validation of Structural Analysis Methodology for Comprehensive Vibration Assessment of Reactor Vessel Internals, Proceedings of the KSME 2010 Fall Annual Meeting, p.950-955, 2010.