Hydraulic Load Analysis for RVI Comprehensive Vibration Assessment Program

Yong Soo Kim*, Kyu Hyung Kim, Jong Ho Lee
Nuclear Engineering & Technology Institute, 25-1, Jang-dong, Yuseong-gu, Daejeon, Republic of Korea, 305-343
**Corresponding author: kysoo1@khnp.co.kr*

1. Introduction

Recently, the US NRC Regulatory Guide 1.20(RG 1.20) was revised to allow the usage of CFD code in the analysis program of a comprehensive vibration assessment program (CVAP) for reactor vessel internals (RVIs) [1]. Thus, the analysis program of Shin-Kori #4 RVI CVAP has been developed according to the revised guideline of RG1.20 Rev. 3.

The analysis program consists of a hydraulic analysis to calculate the hydraulic forcing functions and a structural response analysis with inputting the calculated hydraulic forcing functions on each component of RVIs. The hydraulic forcing functions are comprised of the deterministic loads induced by the rotor and blade of reactor coolant pump (RCP) and the random loads generated by the flow turbulence [2].

In this study, according to the RG1.20 Rev. 3, the hydraulic analysis methodology of RVI CVAP was developed to use the CFD codes. In order to verify the developed hydraulic methodology, the deterministic and random loads of Yonggwang #4 RVIs were calculated with modeling the fluid domain model of reactor vessel in the full 3D and verified through the comparison between the calculated results and the measured data in the Yonggwang #4 RVI CVAP test [3].

2. Hydraulic Analysis Methodology

The hydraulic and structural analysis methodology using CFD code was developed to comply with the revised RG1.20 as shown in Figure 1. The deterministic and random hydraulic forcing functions were assumed to be uncorrelated due to the independent source of each hydraulic forcing function. Thus each hydraulic load can be calculated separately. The deterministic hydraulic forcing function was calculated through the 3D acoustic wave analysis for the RVIs using ANSYS Mechanical. The random hydraulic forcing function was calculated through the full 3D flow analysis with the Detached Eddy Simulation (DES) model using ANSYS CFX. The calculated results for each hydraulic forcing function were used as inputs for the deterministic and random structural response analysis, respectively.

Figure 2 represented the full 3D model for the fluid domain of the Yonggwang #4 reactor vessel. It was modeled with approximately 4 million grids for the deterministic hydraulic analysis and 30 million grids for the random hydraulic analysis.

The following thermal hydraulic conditions of Yonggwang #4 RVI CVAP test were used for the deterministic and random hydraulic analysis [4]:

- Working fluid : Water
- Fluid temperature : 563.9 °F
- Pressure : 2250 psia
- Density : 0.0266 lbm/in^3
- Viscosity : 0.00006066 lbm/ft-s

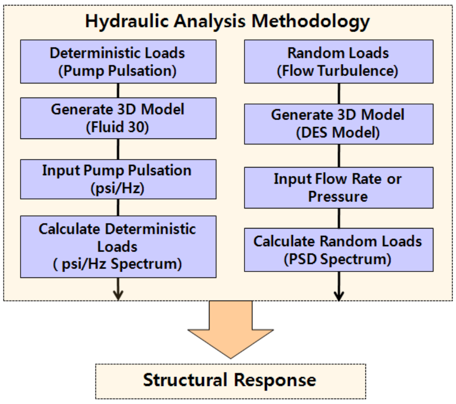

Figure 1 Hydraulic analysis methodology

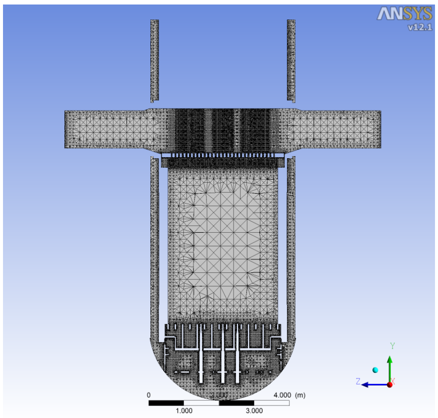

Figure 2 3D fluid domain modeling of RVIs

The pressure pulsations in the inlet of reactor vessel used for the hydraulic analysis of Yonggwang #4 RVI CVAP were inputted for the deterministic load evaluation as listed in Table 1.

Table 1 Pressure vs. frequency

Frequency (Hz)	Pressure (psi)
20	0.17
40	0.05
120	0.2
240	1.07
360	1.12
480	0.5

Also the following RCP design mass flow rate of Yonggwang #4 was inputted for the random load evaluation:

- 166.6×10^6 lbm/hr (per RCP) ×4 RCPs

3. Analysis Results

The pressure distribution in the downcomer for the deterministic load of the pressure pulsation of 480Hz and the random load analysis were shown in Figure 3 and 4, respectively.

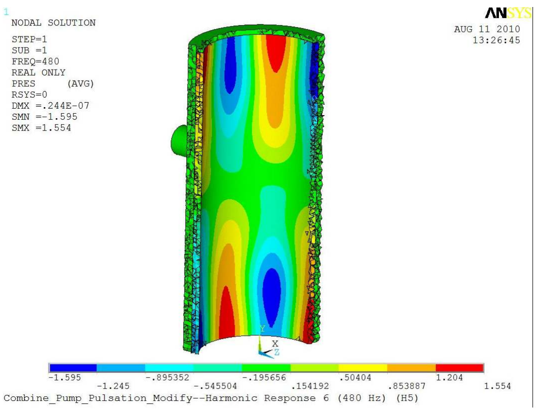

Figure 3 Distribution of deterministic load in downcomer

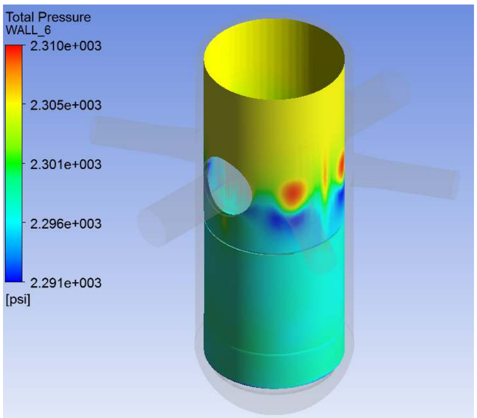

Figure 4 Distribution of Random Load on CSB

As shown in Figure 5, the calculated results of this study were compared with the correlated random hydraulic function from mock-up test results of Palo Verde #1 and the measured values of Yonggwang #4 RVI CVAP. The newly developed hyadraulic analysis methodology estimated the measured values better than the correlated function. However, there were some differences between the calculated and the measured in the low and high frequency region. These differences could be reduced by using the fine mesh model and extending the calculation time for the steady state and the transient. Considering the measurement tine of 30 seconds in Yonggwang #4 RVI CVAP test, the simulation time of 4 seconds for the random hydraulic forcing function was relatively small.

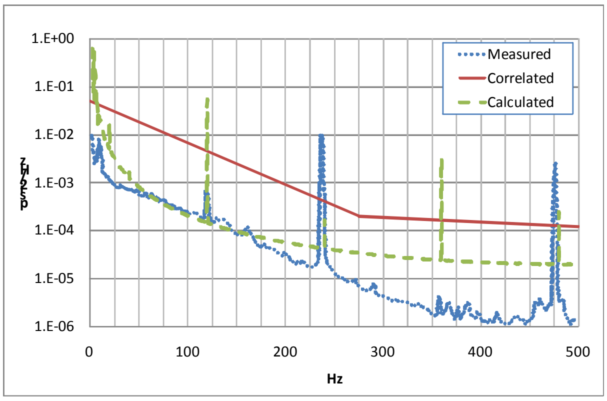

Figure 5 Pressure PSD on UGS support plate

4. Conclusions

In this paper, a hydraulic analysis methodology were developed for RVI CVAP and verified by comparing the calculated results of the newly developed hydraulic analysis methodology with the measured values of Yonggwang #4 RVI CVAP test and the correlated function from mock-up test results. The calculated results agreed with the measured values better than the correlated function. Thus, it was confirmed that the hydraulic analysis methodology was developed properly. As the future works, the developed hydraulic analysis methodology will be improved by extending the simulation time and using the fine mesh. And it will be verified further by comparing between the structural response analysis results with the measured data such as strain and displacement in the Yonggwang #4 RVI CVAP test. The verified methodology in this process is expected to estimate the hydraulic load of Shin-Kori #4 successfully.

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

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

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