Simulation of a Steam Accumulator for the Development of Nuclear Equipment Performance Evaluation System

Kyung Ha Ryu [a*], Byung Duk Kim [a], Jae Hyoung Kim [a], Sang Ho Sohn [a], Jin Wook Ko [a], and Jae Hyun Cho [b]
[a] *Department of Nuclear Industrial Equipment Research, Korea Institute of Machinery and Materials, DaeJun, Korea*
b Nuclear Material Laboratory, Seoul National University
[*]*Corresponding author: khryu@kimm.re.kr*

1. Introduction

The performance evaluation of high capacity and pressure valve used to be conducted in foreign organizations because of absence of test facilities and system in Korea. This has caused expenses, time, and difficulties of maintenance of used equipment in Nuclear Power Plants (NPPs). There were several tries to establish the test equipment, but the attempts have been delayed by lack of performance evaluation and insufficient cost. The demand for equipment of NPPs increases continually for 21 NPPs operated and 7 NPPs constructed. Based on these, technology of the performance qualification test of equipment for high temperature and pressure steam has been developed in Korea Institute of Machinery and Materials (KIMM) [1].

2. Problem Definition

One of the difficulties is constructing and controlling of steam accumulator system. The steam produced by high temperature and pressure boiler should be accumulated in large volume vessel to control the flow rate and pressure with precise. The accumulated steam is condensed and became water. In the case of two phase problem, it is not easy to analyze. In this paper, the MARS (Multi-dimensional Analysis of Reactor Safety) code [2] is used to compute two phase problem.

To set the design concept, the performance analyses are performed. The used model is shown in the fig. 1. The diameter of steam vessel is 1.5 m, and height is 10 m (the volume is 17.67m^3). The material of steam vessel is 316L SS and thickness is 20 cm. The steam of 673K (400^{o}C) and 18.2MPa (180 bar) enters the vessel. Entered steam cools and forms water by room temperature vessel structure or outside air.

3. Analysis Results

3.1 Air Cooling Case

As a severe case, no insulation case is analyzed. At the initial time of analysis, the steam of 98.1 kg/s enters through inlet pipe. In the figure 2, the flow rate decreases from 17 second by decreased pressure difference. The flow rate would not be zero, about 2 kg/s, when the pressure difference becomes almost zero (after 123 second). This is caused by condensing of steam. Condensed water increases with time because of air cooling. The volume void fraction is plotted in fig. 3. In this figure, the volume of vessel is divided into 5 volumes along the height. The water level increases to 97.9% and is saturated. This is caused by initial non-incompressible gas (air) that is initial filled gas on vessel inside.

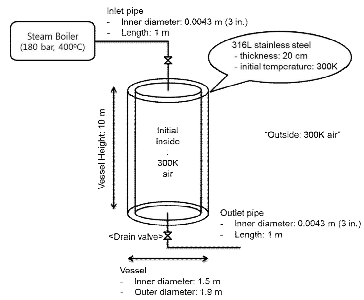

Fig. 1 Analyzed model

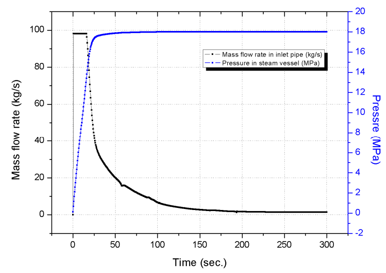

Fig. 2 Mass flow rate and pressure at initial time

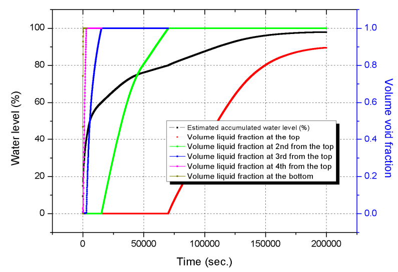

Fig. 3 Water level and volume void fraction of vessel

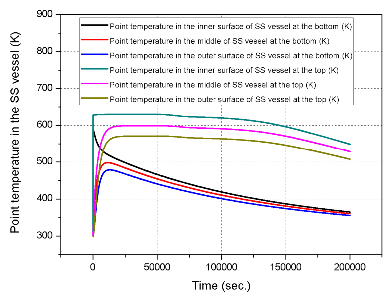

Fig. 4 Temperature variation of vessel sturucture

The temperature differences in vessel structure are relatively large along the height. In the fig. 4, three temperatures (inside, middle and outside of vessel) of bottom and top position are plotted. The temperature of the system decreases with time by air cooling. In the top position, hot steam keep coming and this makes temperature difference.

3.2 Insulated Case

With insulation, the heat loss of steam is used only heating the vessel. As shown in fig. 5, the final water level becomes 57.4% and the water and vapor temperature are from 524.8K to 604.8K along the height.

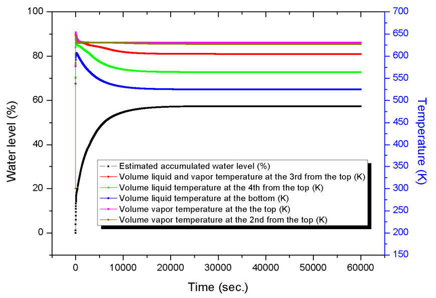

Fig. 5 Water level and temperature of the vessel

3.3 Releasing condensed water case

The condensed water should be released to set the temperature of steam and to accumulate the steam. In this analysis phase, the drain valve is modeled to open with 10% water level and close with 6% water level. The water level and mass flow rate in inlet pipe are plotted in fig. 6.

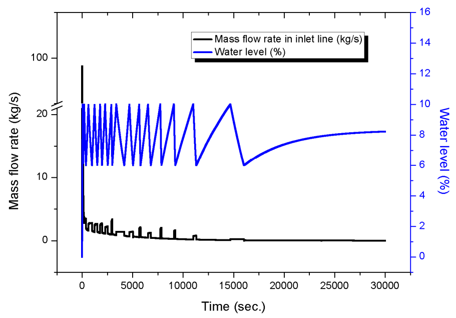

Fig. 6 Water level and inlet mass flow with valve control

Fig. 7 shows flow rate in inlet and outlet line in initial time. In the outlet line, sometimes, reverse flows are shown from 0 to 50 second. This is caused by frequent and sudden pressure changes that cause higher pressure in end of outlet line. As shown in figure 8, the final temperature of steam inside vessel becomes 630.2K. Local temperature of top position is relative high, 644.6K. As shown in figure 9, the temperature differences in vessel structure are not shown along the height. The temperatures behave as 3 groups, which are caused by not height but radial thickness. The final vessel temperature is 629.3K.

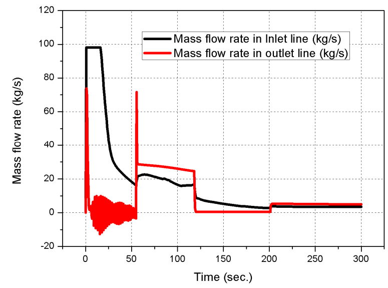

Fig. 7 In and out mass flow rate

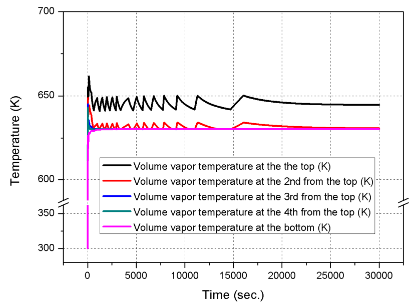

Fig. 8 Steam temperature in the vessel

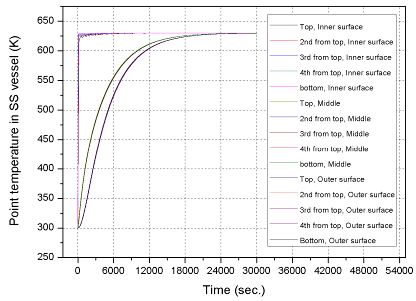

Fig. 9 Temperature of the vessel

3. Conclusions

In this paper, the performance of steam vessel is analyzed. The steam cools and condensate. If the insulations are not sufficient, large temperature difference can be possible. The difference can cause mechanical problem in vessel structure. With insulation, the steam temperature inside vessel would be from 524.8K to 604.8K. The temperature difference is shown with height.

Releasing the condensed water with drain valve control, there are no temperature difference of the structure. The final vapor temperature would be 629.3K.

The performance qualification test facility for steam equipment are constructing in KIMM in this year. The results of this paper are used to the system.

REFERENCES

[1] Technology development of operating performance test for steam equipment, Phase I report, The Ministry of Knowledge Economy 2008.

[2] MARS code manual, technical report 2812, KAERI, 2006