Water Hammer Analysis using RELAP5/MOD 3.3 for Yonggwang Nuclear Power Unit 1&2 Blowdown System

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1. Introduction

Water hammer can be defined as a rapid pressure step occurring in the liquid in a closed pipe caused by a sudden change in the liquid velocity. This pressure acts for a period which is twice the transit time of sonic wave in the pipe. Generally, water hammer can occur in any thermal-hydraulic systems like nuclear power plant and is extremely dangerous for nuclear power plant piping system since, if the pressure induced exceeds the pressure range of the pipe given by the manufacturer, it can lead to the failure of the piping system integrity.

For Yonggwang nuclear power unit 1&2, water hammer occurred repeatedly on the outlet piping of regenerative heat exchanger of steam generator blowdown system.[1] Thus, design modification was performed to prevent the water hammer and the analysis of effect on water hammer before and after design modification was performed to verify the validity of the design modification.

2. Analysis Methods and Results

The transient analysis for steam generator blowdown system of Yonggwang nuclear power unit 1&2 was performed using RELAP5/MOD 3.3 and the specification of the computer used was as below.

Table 1. Specification of Computer Used

Operating system	Microsoft windows XP professional K
System	32bit
Processor	Intel® core™ i5 CPU 750@2.67GHz

2.1 System Modeling

It is identified that RELAP 5 code relatively predicts the water hammer [2] derived from rapid valve closure well, while responds sensitively to the selection of time step and node size for analyzing the water hammer[3] derived from condensation.

The piping modeling consisted of total 150 nodes and 76 junctions and each node size was adjusted not to exceed 0.5m based on the result of sensitivity analysis. Fig 1 shows the nodalization used for this analysis, and illustrates the nodalization difference before and after design modification and most significant modification was the length of the back end of the control valve, which was changed from 70m to 10m.

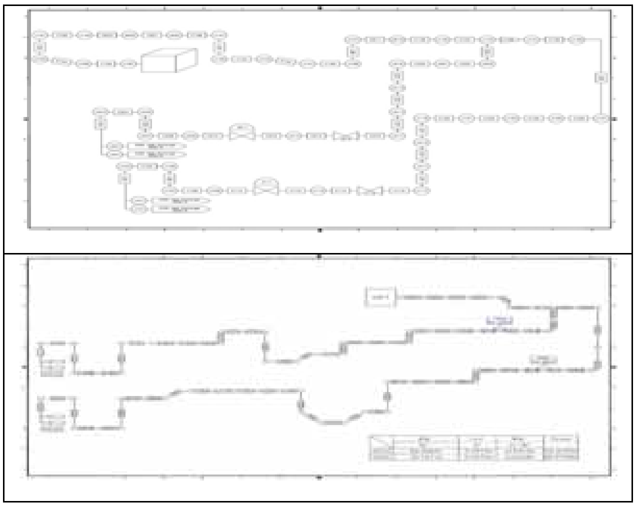

Fig 1. Comparison of Nodalization Before and After Design Modification

We recognized the importance of node size and time step in the water hammer analysis[3], thus we performed sensitivity analysis by Courant limit.

$$\delta t \leq \delta x / v$$

δt : Time step
δx : Node size
v : sonic velocity

As a result of the sensitivity analysis, the node size and time step were selected as 0.5 m and 0.000324 sec, respectively.

2.2 Analysis case

For the selection of analysis case, we surveyed the accident cases[4] occurred at steam generator blowdown system and its result is as follows:

Case 1 : Inflow of hot cooling water before system is preheated when operating after plant shutdown
Case 2 : Inflow of cold cooling water due to the closure of isolation valve of blowdown system during normal operation of plant
Case 3 : Leakage due to malfunction of valve closure

2.3 Initial conditions

For the analysis, the following initial conditions were used:

Case No.	Flow Rate (gpm)	Pressure (kPa)		Temperature (K)	
		HEX exit	HDT	HEX exit	HDT
Case 1	494	4164	101	296.15	373.15
Case 2	494	3130	882.6	463.15	174.56
Case 3	-	4929	882.6	296.15	447.71

Note : HEX : Regenerative heat exchanger
HDT : Heat Drain Tank

2.3 Analysis results

We compared the analysis result for before and after design modification and summarized the result as follows:

1. Figure 2, 3, 4 shows the comparison of the pressure results between the before and after design modification for Case 1, 2, 3. The result shows that the pressure peak after design modification is lower than that before design modification
2. It is founded that the main reason for the prevention of the water hammer is the reduction of the region where the cold water meet the steam and water.
3. In case of the water hammer due to the leakage, the design modification has much effect in decreasing the pressure peak occurred by the water hammer

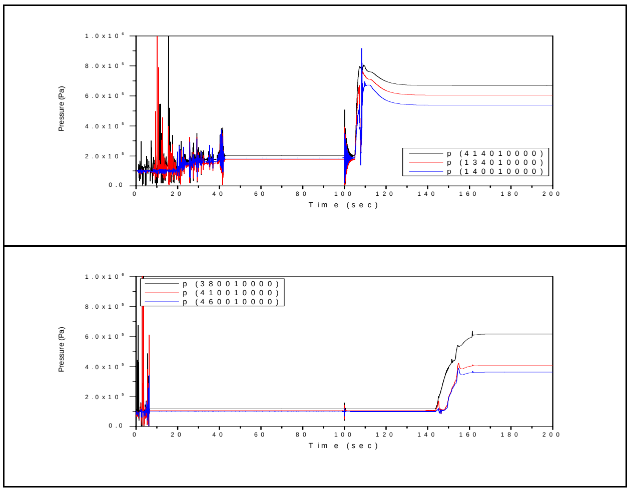

Fig 2. Comparison of Pressure Result for Case 1

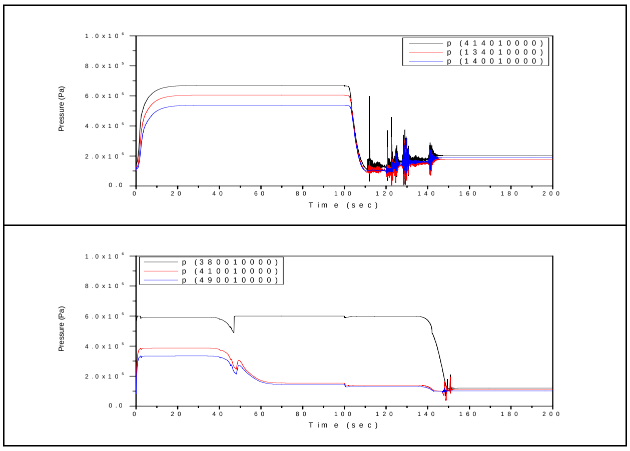

Fig 3. Comparison of Pressure Result for Case 2

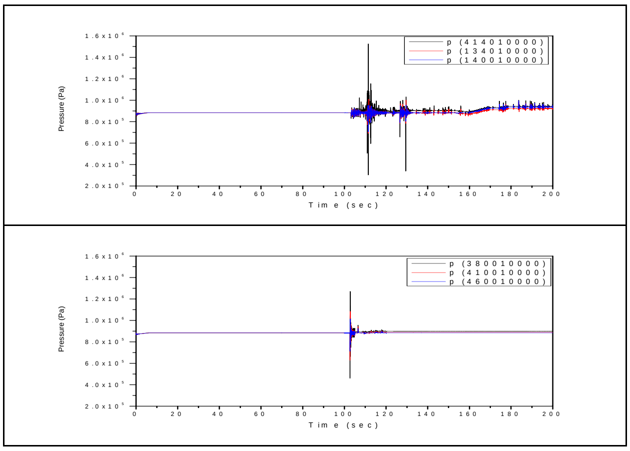

Fig 4. Comparison of Pressure Result for Case 3

3. Conclusions

Based on this analysis result, adopting design modification plan including the reduction of the piping length from the exit of control valve to the heat drain tank has much effect on preventing the condensation-induced-water hammer. This kind of the design modification should be considered in the other nuclear power plants in which the water hammer frequently occurred

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