Development of CFD Analysis Methodology of Hydraulic Load Evaluation in POSRV Piping System

Tae-hyeon. Kim [a], *Young-jo. Choi* [b], Jong-pil. Park [a], Won-tae. Kim [a], Byung-sub. Han [a]
[a]*ENESYS Co., 328, Guam-dong, Yuseong-Gu, Daejeon, 305-800, Korea*
[b]*Korea Hydro & Nuclear Power Co., 25-1, Jang-Dong, Yuseong-Gu, Daejeon, 305-343, Korea*

1. Introduction

APR1400 has been improved as an advanced light-water reactor that adopts new technology's. One of major technologies is IRWST(In-containment Refueling Water Storage Tank) placed inside containment. In order to adjust the new technology when POSRV(Pilot Operated Safety Relief Valve) is opened, POSRV-IRWST linked line must be kept safe. Theoretical solution and experimental data are needed for structure integrity, but proven data are insufficient from the viewpoint of hydrodynamics. The hydrodynamic flow analysis and the thermodynamic behavior analysis should be performed by using CFD.

The objective of this study is to develop the CFD analysis methodology of hydraulic load evaluation in IRWST piping system. This method is a basic hydraulic load evaluation in POSRV piping system. Also, this will help to analyze fluid-structural interface and to predict special phenomena. Therefore, that can be used as a basis to the most suitable design.

2. Methods and Results

In order to study structural impact of piping system, CFD analysis was performed to obtain the pattern of flow for a characteristic of POSRV opening and the designed condition of mass flow rate in piping system.

2.1 Three-Dimension CAD Model

A three-Dimension model of POSRV piping system is formed using 3D CAD tools and a fluid domain is extracted from a 3-D model by a boolean method.

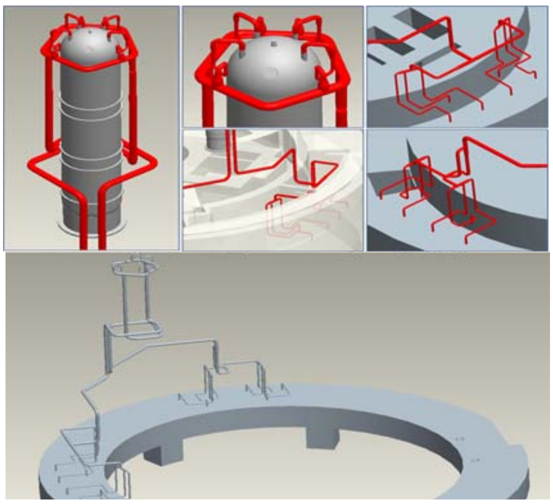

Fig. 1. 3D CAD domain for pipe line from POSRV to IRWST

2.2 Mesh Generation

POSRV piping system consists of connection pipe between pressurizer and POSRV, POSR valves, common head and discharging pipe to IRWST. The reason why the tetrahedral mesh was used is that the overall piping system is relatively long composed to pipe diameter.

Therefore, meshes generated a tetrahedral mesh for keep in complicated piping form. Also, meshes which are near pipe wall are generated in the shape of prism to consider a wall function. Detailed form of meshes are shown in fig. 2

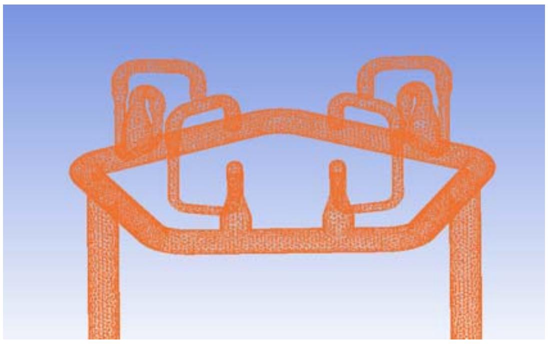

Fig. 2. Mesh generation for calculation domain

2.3 Operating Condition

Boundaries of POSRV piping system are given at the upstream of POSRV and IRWST.

The four POSRVs perform the overpressure protection function and rapid depressurization function of the Reactor Coolant System. Set pressure adjustment at normal operating conditions. Detailed values of operating conditions are listed in Table 1.

Table 1. Designed operating conditions

Operating Condition	Value
Open/close set pressure	2338 psig
Flow rate	540,000 lbm/hr × 4EA
Open/close stroke time	0.8/1.1 sec. (including Dead Time)

* Reference for APR1400 homepage. (http://www.apr1400.com)

Boundary conditions are atmospheric pressure in the upper position of IRWST and mass flow rate of POSRV opening condition.

The fluid material property is assumed water at 600 K. Inlet velocity is assumed 25 m/s that the velocity calculate of inlet area and mass flow rate in table 1. Outlet pressure is assumed atmospheric.

CFD analysis for POSRV opening condition is performed about 3 characteristics of linear, logarithmic and exponential types. The study compares flow patterns in unsteady state for each inlet velocity according to POSRV open conditions(Fig. 3).

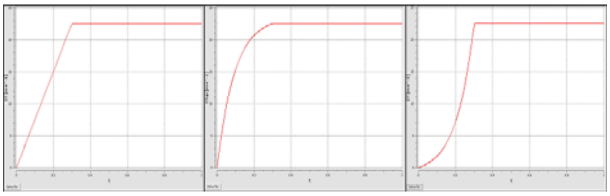

Fig. 3. Inlet velocity according to POSRV opening conditions

2.4 Result

Mass flow rate for each case head to the maximum flow for 0.8 seconds after POSRV open. Then, flow becomes steady due to a constant system pressure.

Figure 4 shows a flow distribution at the upper position of POSRV pipe system.

According to CFD analysis results, the time of flow stability and swirl generation varies as characteristic of discharger flow rate.

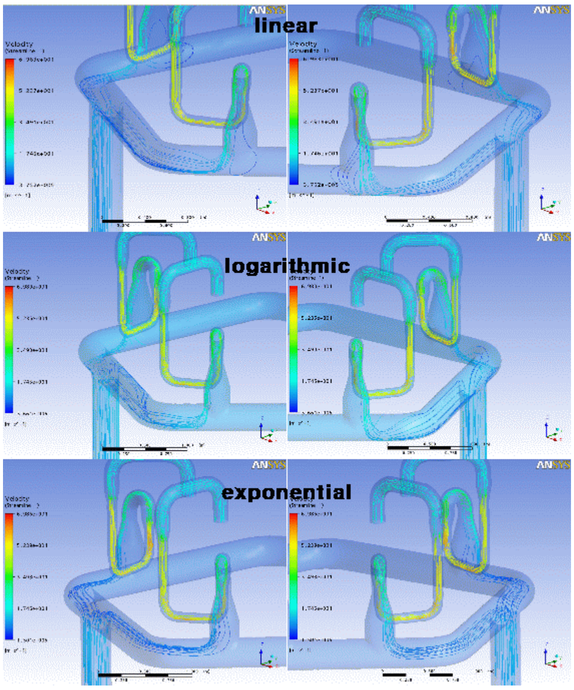

Fig. 4. Stream line according to POSRV operating condition

Asymmetry load in POSRV piping system is confirmed by contour of a velocity and a pressure in CFD result.

Figure 5 shows a result which compares a value for contour of a velocity in the upper / middle / lower positions of POSRV piping system.

Base on the CFD results, asymmetry load is expected.

Mass flow rate and streamline direction according to piping system positions and formations differ at the flow regime of branches.

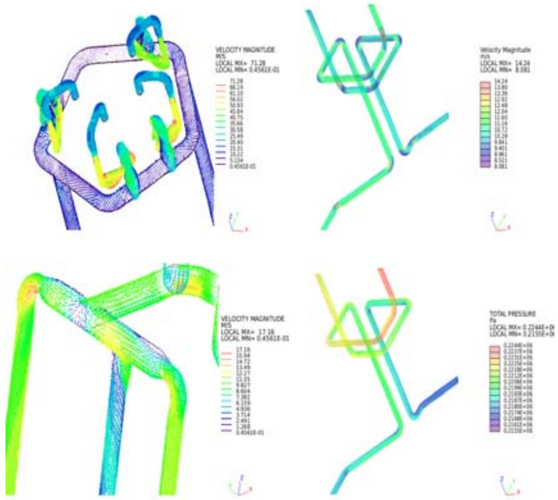

Fig. 5. Velocity magnitude and pressure distribution according to elevations of pipe line

3. Conclusions

Established lumped code has a limitation in showing local hydraulic behaviors such as two-dimensional flow direction and pressure distribution.

Fluid-structural interface analysis of POSRV piping system is needed to confirm a structure integrity.

On the basis of this study, CFD analysis is required to examine thermal-hydraulic effects on the POSRV piping system and related structures.

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