Flow Resistance and Pressure Drop Analysis in the Pressurizer Spray Piping at Shutdown Mode for Kori 1 Unit

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1. Introduction

It has been recently found that the spray capability of nuclear power plant (NPP) Kori 1 unit was not in accordance with the technical specification of Emergency Operating Procedures (EOP) [1]. Although the reactor coolant pump (RCP) and the spray valve were operating well during the shutdown operation, reactor coolant system (RCS) pressure hardly ever went down. It is different from the bases of the EOP's technical specification. Moreover, it has been reported that Kori 2 unit took a similar experience. So this study has been carrying to analyze the cause of the phenomena with a computational fluid dynamics (CFD) tool [2] . And the results will be applicable to EOP revision, input data of Nuclear Plant Analyzer (NPA) and the plant simulator.

2. Analysis Method

2.1 Spray capability

Kori 1 unit as a type of Westinghouse nuclear power plant has two loops which cool down the reactor coolant system (RCS) and two spray valves to bring down the pressure as shown in the figure 1.

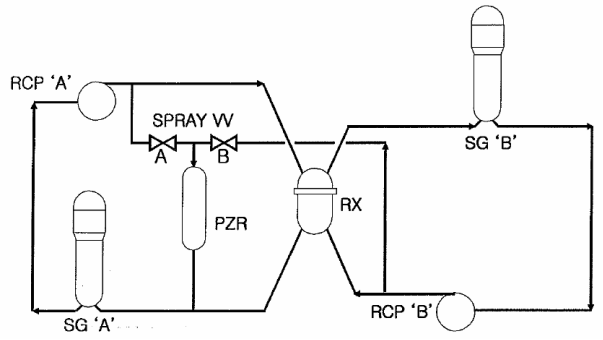


Figure 1. RCS flow path of Kori 1 unit

According to EOP's technical specification [2] of Kori 1 unit, the spray capability is determined by how to operate RCPs as shown in the Table 1.Most of the cases have a certain spray capability except case III. But, the plant during its overhaul period has recently experienced a difference case not in accordance with the technical specification. In order to examine the matter closely, it needs to estimate the flow resistance and pressure drop through the spray pipe A and B.

Table 1. Results of Spray capability analysis in EOP's technical specification of Kori 1 unit

Case	Operating Pump	Opening Valve	Spray Capability
I	A	A	Available
II	A	B	Available
III	B	A	Not Available
IV	B	B	Available
V	A, B	A	Available
VI	A, B	B	Available

2.2 3D CAD Modeling and Meshes

First of all, it is important to construct a detail 3D geometry for CFD analysis. Three dimensional geometry design data for the plant were acquired from the piping and instrumentation diagram (P&ID), iso-metric drawing, general arrangement drawing and other drawings and documents related to spray piping system of Kori 1 unit. Figure 2 illustrates the 3D CAD model. The spray piping is linked from each cold leg of RCS to spray valve. So the pipe consists of two flow paths, which are called spray piping path A and B.

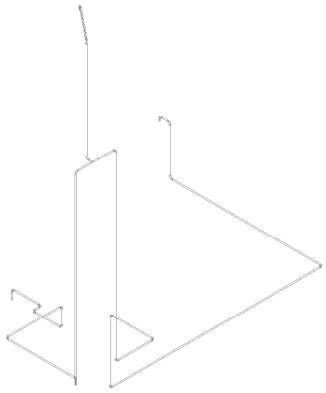
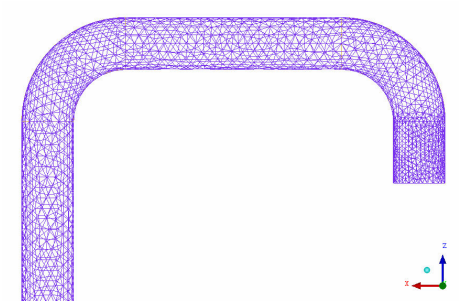


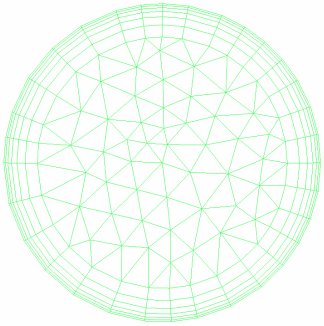
Figure 2. 3D CAD Modeling of the spray piping of Kori 1 unit

The 3D model for mesh construction and CFD analysis divided each flow path A and B. Mesh work is one of the most important elements for CFD analysis. It has been revealed that mesh shape and size affect an accuracy of CFD analysis. In order to minimize the effect, mesh was made of sufficiently smaller size than its diameter and tetra shape was selected as shown in Figure 1(a). And concerning boundary layer effect,

boundary layer was formed densely as shown in Figure 1(B). Number of total mesh elements is about 1,500,000.



(a) Some meshes around the spray pipe inlet



(b) Cross-section meshes with boundary layers for the spray pipe

Figure 3. Meshes for CFD analysis

3. Results

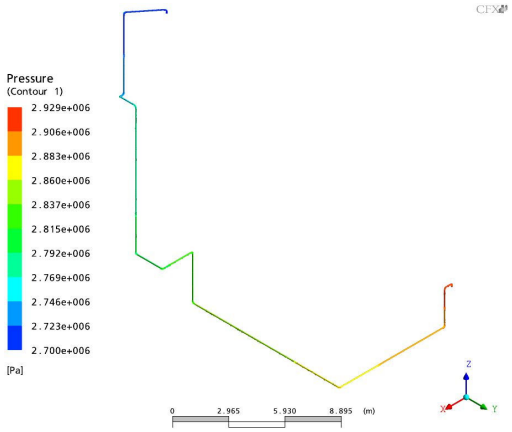
Steady state calculation under shutdown mode operation condition for all of the hydraulic system was performed to determine the water properties and other boundary conditions using RELAP5/Mod3.3. The calculation results applied to CFD analysis.

Each boundary condition for inlet, outlet and wall was applied to flow rate, static pressure, and no slip condition respectively. And RNG k-ε model was selected as the turbulence Model. Convergence criteria for mass and momentum was 10E-5. The criteria is very tight convergence [3].

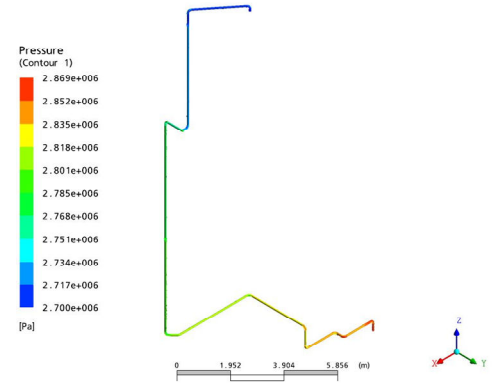
Figure 4 shows the analysis results for pressure drop through the spray pipe flow path A and B. the pressure drop in the path A is larger than that of the path B. It means that the spray capability depends on its flow path.

4. Conclusion

The spray capability under a certain operation condition is important for safe operation of NPP. Recently, at Kori 1 unit, it has been issued to confirm the capability again. So this CFD analysis has been carrying to examine the matter. According to the analysis results, it is clear that the pressure drop and flow resistance depend on the flow path and it affects the spray capability. To solve this problem, a more detail analysis for various cases will be accomplished



(a) Spray pipe flow path A



(b) Spray pipe flow path B

Figure 4. Pressure drop in the spray pipe A and B by CFD analysis

REFERENCES

[1] KEPCO, Emergency Operating Procedures for Kori 1 unit, Revision 8, 2003
[2] KEPCO, Technical Specification of the Emergency Operating Procedures for Kori 1 unit
[3] ANSYS Ltd., CFX Solver Modelling, 2004