Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Simulation of Cooling Performance for Permanent Cavity Seal Ring

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1. Introduction

Recently, for the safety operation and reduction of overhaul period, most of nuclear power plant utilities install reactor cavity seal ring permanently. Moreover, permanent cavity seal ring (PCSR) has been designed based on the safety criteria compared cooling performance before with after installation. The purpose of cooling performance analysis is to investigate influence of cooling path after the shape change or area change. In this simulation, design criteria and optimized hatch area are described for installation of Permanent Cavity Seal ring

2. Methods and Results

From on the construction data and drawing in the operating nuclear power plant, structural and fluid geometry was created. And mesh model was optimized through quite a few iteration of solving verification model. Then, based on the PCSR design, cooling performance was analyzed according to the number and shape of PCSR hatch.

2.1 Assumption of Safety Criteria

In this simulation, the Safety Criteria for cavity cooling was assumed as follows. The reactor Type is 3 Loop. The temperature of containment is 16°C ~ 49 °C and the temperature of concrete surface has to be kept within 65 °C. The temperature of adiabatic materials covering reactor has to be kept within 73 °C. The capacity of cooling fan is 580 ㎥/min (20,500 CFM) and only one cooling fan is operated.

2.2Geometry and Mesh Modeling

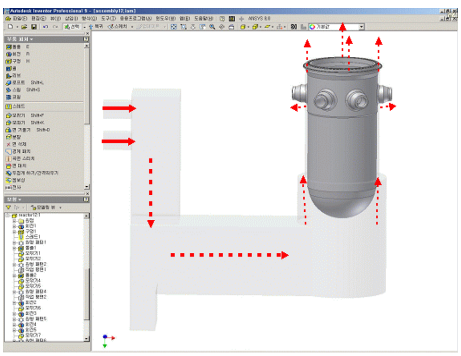

Figure 1. Cavity Cooling Path

As the Figure 1, the cooling air from cavity cooling fan pass through the low part of the nuclear reactor, then lead to cavity through the hole of cavity sealing or it is withdrawn through twelve ducts.

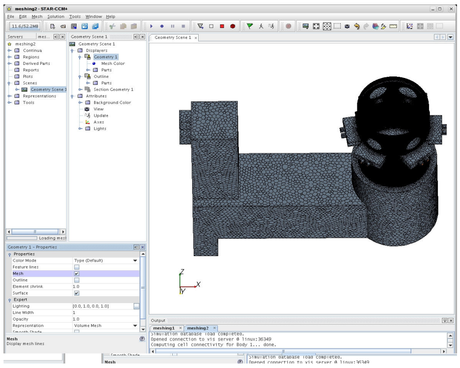

Figure 2. Polyhedral Meshing Model

The cavity sealing space in the Figure 2 is small in comparison with whole model. So mesh quality was reinforced for the accuracy and polyhedral mesh was chosen for the convergence of fluid dynamic analysis.

Commercial analysis program, STAR-CD Ver. 4.0 and High Reynolds k-e model as turbulent model were used. About 600,000 polyhedral meshing were used and iterated 400~ 500 times.

2.3 CFD Analysis and Results

As the following Figure 3, the temperature of the cavity before PCSR installation was 293～319 °K (20～46℃), the temperature of the concrete was 309～314 °K (36～41℃), like assumption of safety criteria

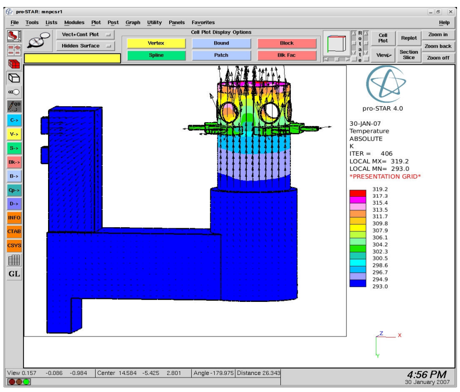

Figure 3. Before installation of PCSR

Case study was performed for this PCSR, The result in case of 8 hole installation is as the following Figure 4.

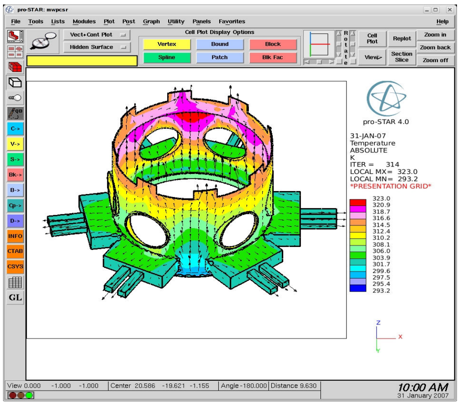

Figure 4. Case Study (8 Hole)

As a result of this simulation, the temperature of PCSR in cavity was 310～323 °K (37～50℃), that of concrete was 310 ～ 316 °K (37 ～ 43℃). They corresponded to the assumption of safety criteria (Cavity:16～51℃, Concrete : 65℃) but a little higher than it . The increase in temperature would be locally shown in the geometry. So six holes were installed not to increase the temperature.

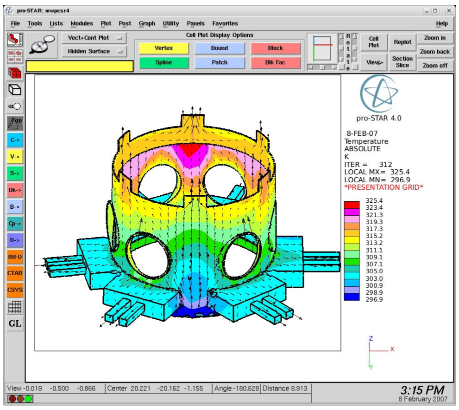

Figure 5. Case Study (6 Hole)

As the Figure 5, the temperature of PCSR was 313～325 °K (40～52℃), that of concrete was 313～319 °K (40～47℃). They were within the assumption of design criteria (Cavity: 16 ～ 51℃, Concrete: 65℃). The increase in temperature was somewhat relieved and the pressure was normally distributed. So they helped to make cooling path.

3. Conclusion

The performance of cavity cooling is in proportion to opened area, six opened holes are suitable. Because the position of PCSR has an influence on cooling path, it is posited carefully. It is required to simulate cooling performance after considering geometry, the number and area of the holes. Thus, this paper will be useful for the method of safety analysis in the installation of PCSR

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