Comparison of CFD Analysis Methodology for SFP Cooling Performance Evaluation

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1. Introduction

The cooling performance evaluation of spent fuel pool(SFP) is necessary to verify for spent fuel safety with racks configuration. The adequacy of external cooling by SFP cooling system and of internal pool water circulation by natural convection are analyzed with SFP filled to full storage capacity about 20 years storage. In order to take into account the interaction between the racks, which is not considered in convectional Computational Fluid Dynamics(CFD) methods, which enables to analyze the global behavior of the cooling pool including particularities of all racks. Thus, it is possible to determine mass flow rates flowing through each of the racks, and therefore the temperature distribution. CFD results should show that maximum local water temperature and cladding temperatures lower than the saturation temperature, thus, localized boiling will not occur. In CFD calculation, it is very important to determine the analysis methodology. Therefore, I compared the SFP licensing report of Hanul 2 with realistic CFD analysis models and assessed the impact of model difference.

2. CFD Model for Licensing

The analysis criteria is that each of the redundant spent fuel pit cooling system trains, during normal operation, is designed to remove the heat loads of normal storage of 1,062 assemblies with a burnup of 60,000 MWD/MTU and stored for 17 months up to 22.6 years. At that case, the maximum normal temperature is 66℃. The pool size of south-north, east-west and pool water depth are 12.6 m, 8.0 m and 12.06 m, respectively. The active length of fuel assembly is 3.658 m and cell pitch of racks are 0.2848 m.

The pool and pipes are modeled according to their geometrical characteristics. In order to avoid a detailed CFD model of each fuel assembly, what is impossible from the computational point of view, equivalent racks have been used in the CFD model. These equivalent racks are based on the porous domain approach. A porous domain is a fluid volume region where specific parameters can be defined in order to obtain the same physical behavior of the region, not been necessary a real detailed model of the racks. The CFD code solves the whole fluid domain, thus temperature distribution is obtained for any point of the SFP. Figure 1 shows the CFD model using in thermal-hydraulic licensing reports. Decay heat from freshly discharged fuels modeled as a two zone heat source in the center of the racks, conservatively. Decay heat from previously discharged fuel assemblies is applied to the balance of the fuel racks region. Temperature contour in a vertical cross-section of the hot fuel region is shown in Figure 2. The plots confirm that hot fuel is safely and reliably cooled by thermosiphon action. Cold water is rising up in the hot fuel rack cells from the bottom and hot water issuing out of the top of the rack cells. Local hot spots induced by water circulation in the racks is rapidly dissipated in the pool water resulting in a nearly uniform temperature distribution away from the hot racks. Maximum local water temperature and cladding temperature for the evaluated case are 63.9℃

and 87℃, respectively. The saturation temperature for water at this local pressure is given as 115℃, it is concluded that local water and cladding temperature remains below saturation.

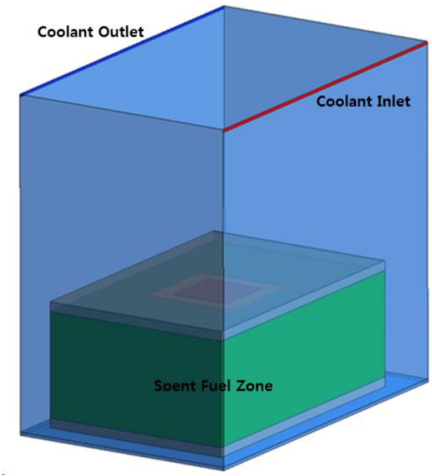

Fig. 1. The CFD model for licensing.

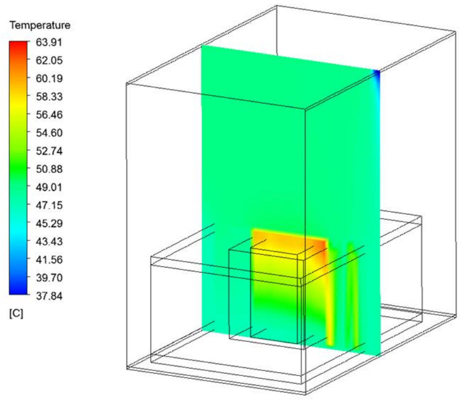

Fig. 2. Temperature contour of licensing model.

3. Realistic CFD analysis model

The realistic CFD model is similar to licensing model except for the region 1 and 2 racks layout. A schematic of the realistic model is shown in Figure 3. At the center of the pool where racks are fully surrounded by other racks. The Surrounding racks are demanding coolant from the closets regions. Since the inter rack space is not modeled, the central rack (with higher decay heat) can be only feeded by the rack to pool bottom space dealing with the surrounding racks, what makes a conservative isolation effect. Maximum local water temperature and cladding temperature for the evaluated case are 62℃ and 85℃, respectively. It is also concluded that local water and cladding temperature remains below saturation.

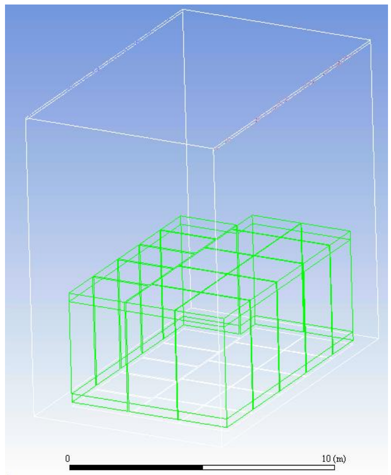

Fig. 3. The realistic CFD model.

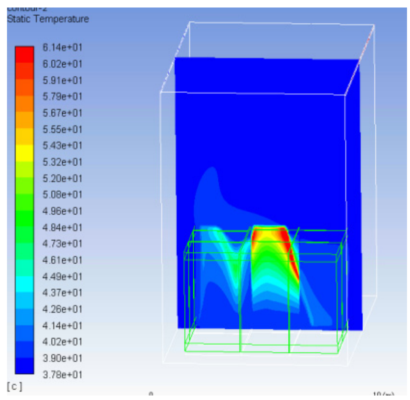

Fig. 4. Temperature contour of realistic model.

4. Discussion

CFD results of the SFP licensing report in Hanul 2 are compared with the realistic CFD analysis models. Maximum local water temperature of licensing model was evaluated to be higher than the maximum temperature of realistic model. Therefore, licensing model is more conservative than realistic model. If using a realistic model in the thermal evaluation of SFPs, we can achieve more heat margin.