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CFD Prediction of AFW Pump Room Temperature in Ulchin Units 3&4

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1. Introduction

For the loss of the HVAC(Heating, Ventilation, and Air Condition) system in NPP's, it is one of the main issues in a PSA(Probabilistic Safety Assessment) FT(Fault Tree) model to estimate the transient temperature variations of some component rooms such as the CS pump, LPSI room, HPSI room, and AFW(Auxiliary Feed Water) room, etc. The air temperature of these component rooms would increase gradually in the case of a loss of the HVAC. The operable temperature of AFW pump room is 160^{o}F(71.1^{o}C), according to ref. [1]. It is a main concern to determine whether the component room temperature exceeds the operability condition and which action reduces the room temperature in the case of a HVAC function failure. A previous study by the authors[2] gives an example of using the CFD method for evaluating the component room temperatures for the loss of the HVAC. The characteristics of this room temperature case would be the natural convective heating of air in a closed or an open room with a considerable complex geometry. The purpose of this study is to estimate AFW pump room temperature during the loss of the HVAC by using CFD technique.[3]

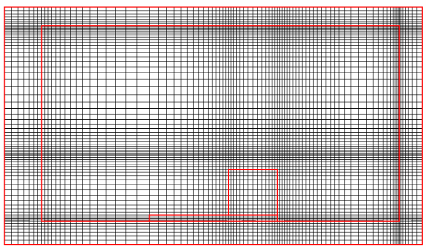
2. Methodology

The MD(Motor Driven) AFW pump rooms of Ulchin Units 3&4 are hexahedral concrete room of 42.0 x 24.0 ft^2 with 21.0 ft height. The thickness of concrete walls is 1.5 ~ 4.0 ft. The motor is located in the center of the room, and a pump, pipes and electric equipments are connected to the motor. The room also has some ducts of the building AC system and a cubical cooler, which is assumed to be malfunctioned in this analysis.

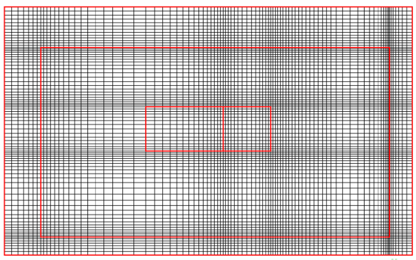
2.1 Problem Definition

A commercial CFD code, CFX-10(ANSYS Inc.), is used for the simulation. The working fluid is air initially at the room temperature and the computational domain includes room air, pump, and concrete walls. Buoyancy force induced by surface heating and cooling was modeled by the Boussineq Approximation. The applied numerical scheme is the high resolution scheme.[3] A structured mesh of 91x82x72 (537,264 cells) as shown in Fig. 1 was generated and used for transient analysis. The assumptions are as follows:

1. The obstacles inside the pump room including a cubicle cooler, pipes, electric devices and lines, and compressor are omitted. These obstacles could disturb the air circulation, but, on the other hand, the structure mostly made by metal could work as heat sinks. Therefore, the omission is considered to be conservative. The total volume of these obstacles is less than 10% total volume of the AFW pump room.
2. The heat is assumed to be only generated in the motor. From the component design manual, the heat released to room at maximum operating load including motor driver is 102,360 Btu/hr(8327.4 W/m^3). In the aspect of room temperature, the excessive heat transfer from motor to room air associated with the lower heat transfer from room air to concrete walls are conservative. To make easier heat dissipation from motor to room air, the motor is assumed to be porous media. If one set the motor as a solid block, the heat transfer to air is less than real and solid motor temperature will increase unrealistically. The reason is because the heat removal equipments such as fins were not modeled appropriately.
3. Size of the room and the motor, location of the motor, and outer wall thickness are modeled as close to the real AFW Pump Rooms as possible.
4. Small holes around the penetrations of pipes and electric lines, and the small windows above the door to balance the air intake and outflow are ignored.
5. The door is closed and lights are off. The motor size is 1.5 x 1.6 x 1.5 m^3.



(a) Side View



(b) Top View

Figure 1. Streamlines predicted by using CFX-10, with an 80X80 grid

2.2 Mesh Sensitivity

Finer meshes decrease the discretization error but consume more memory and computing time. Thus, the selection of adequate mesh size is very critical for the long-term transient calculation like this case. The coarser mesh of Fig. 1 is compared with a very fine mesh of 134 x 99 x 98 (1,300,068 cells). For the comparison, steady-state calculations were conducted with constant temperature boundary conditions on the outer walls. The temperature difference between the fine and the coarse meshes is small over the domain, then it is concluded that the coarser mesh produces reasonable results with small errors and can be used for transient calculations.

3. Transient Temperature Prediction

Transient temperature of AFW pump room is predicted for 2 hours after Loss of HVAC. The initial air temperature is set as 35°C. The time step was set as 0.5 sec, and the energy balance was checked every time stepping. Figure 2 shows temperature distribution and a velocity field on the vertical center plane at time = 4200 sec. The temperature in the upper region is higher than that of the lower region. And the temperature difference of air and pump surfaces are as low as ~10°C due to the porous media assumption. In Fig. 2(b), large air re-circulations are observed as expected.

Figure 3 presents the volume-averaged temperature of the AFW pump room air for Loss of HVAC. The air temperature increase rapidly until ~ 1000 sec, then the increasing speed is slowed down. At 2 hours after Loss of HVAC, the room air temperature reaches over 50°C. But it is estimated that the temperature would not exceed 71°C within 10 hours if the temperature increasing speed remain constant.

4. Conclusions

The CFD analysis has been performed to simulate the heat-up of air in a MD AFW pump room for Loss of HVAC. To select adequate mesh for transient calculation, the steady-state results are compared with those of the very fine mesh. A transient calculation until 2 hours gives the volume-averaged air temperature of about 50°C.

Acknowledgement

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REFERENCES

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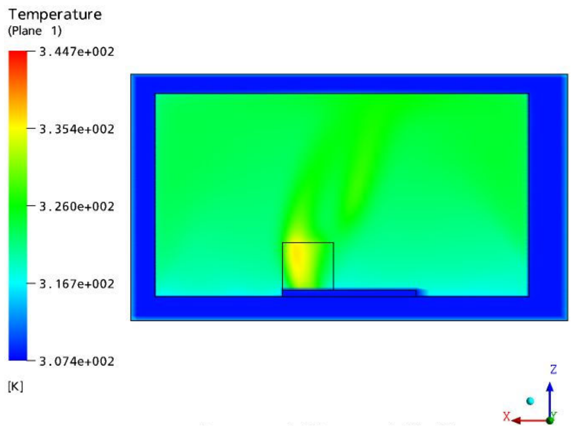
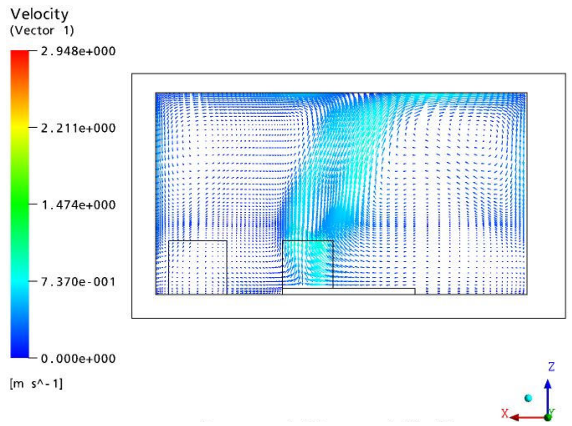
[2] M. Hwang, C. Yoon, J.-E. Yang, & Joo Hwan Park, Review of the Operability for the Components Under the Loss of the HVAC System of the Pump Room, *Transactions of the Korean Nuclear Society*, Autumn Meeting, Busan, Korea, Oct. 27-28, 2005.

[3] *CFX-5: Solver Theory*, ANSYS Canada Ltd., Canada, 1996.



(a) Temperature Distribution



(b) Velocity Vector Field

Figure 2. Computational Results of the Center Plane at 4200 sec

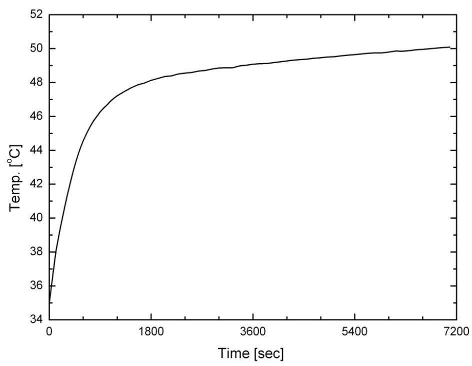


Figure 3. Predicted Volume-Averaged Temperature of the AFW Pump Room Air for Loss of HVAC