Preliminary CFD Analysis for HVAC System Design of a Containment Building

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1. Introduction

HVAC (Heating, Ventilation, Air Conditioning) system has been mainly designed based on overall heat balance and averaging concepts, which is simple and useful for designing overall system. However, such a method has the disadvantage that cannot predict the local flow and temperature distributions in a containment building. In this study, a CFD (Computational Fluid Dynamics) preliminary analysis is carried out to obtain detailed flow and temperature distributions in a containment building and to ensure that such information can be obtained via CFD analysis. This approach can be useful for hydrogen analysis in an accident related to hydrogen released into a containment building.

2. HVAC system in a containment building

The HVAC system of the reactor containment building of APR 1400 consists of the air handling units(AHUs), ducts, reactor containment fan coolers(RCFCs) and etc. Air is basically supplied to the reactor cavity area, steam generator area, and others area through the AHUs. The temperature of the air flowing into these regions is raised by heat emitted from heating equipment and it flows to the upper containment area. To control the temperature inside of the containment building, the air is cooled down by the reactor containment fan cooler and it supplies the cold air to the lower area of the building. The HVAC system in the reactor containment building is simply shown in Fig.1.

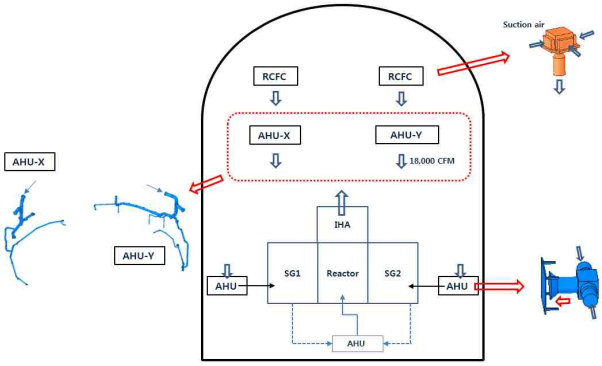


Fig. 1 HVAC system in the reactor containment building

3. The three-dimensional models for CFD analysis

The three-dimensional model for CFD preliminary analysis is shown in Fig. 2. The model is composed of concrete, HVAC system, and heating equipment, and etc. The CFD model is mainly generated in consideration of major (large) equipment and parts which can affect the flow and temperature distribution. The number of grids for CFD analysis is approximately about 20 million.

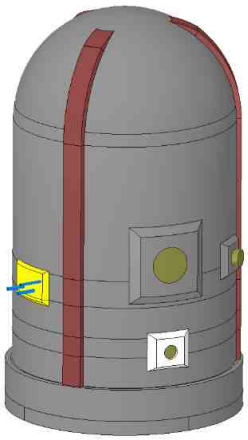


Fig. 2 The 3D model of the reactor containment building

4. CFD methodology

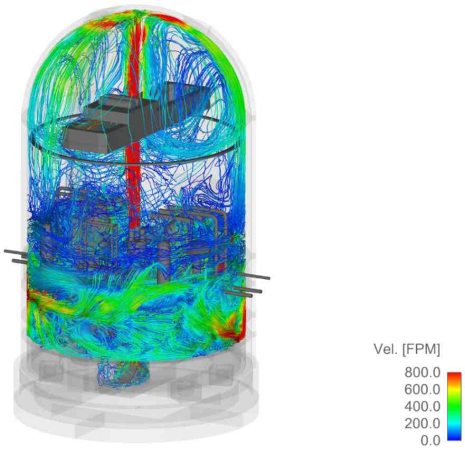
Three-dimensional CFD analysis is carried out to obtain the fluid flow and temperature distribution in the reactor containment building. The CFD analysis is performed in the steady state assumption. To calculate the flow field, the continuity and momentum equations have been used. And k-ε turbulence model is also adopted to consider turbulent effect. Also, the energy equation is solved together including Boussineq approximation[1]

The heating parts(equipment) applied to the containment building are as follows: Reactor, Steam generators, Pressurizer, Integrated head assembly, Reactor containment fan cooler, ICI chase, HX room, Drain tank room, Pressurizer spray valve rooms, Containment annulus area 1/2 and etc. The flow conditions applied to the containment building are based on APR1400 design specifications.

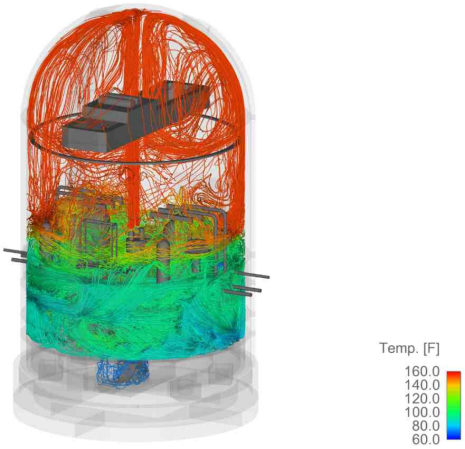
5. Results

Three-dimensional CFD analysis has been performed to obtain the fluid flow and temperature distribution in the reactor containment building. Fig.3 shows the streamline; (a) colored by velocity, (b) colored by temperature. Fig.4 shows velocity distribution in the reactor containment building. The temperature distribution in the reactor containment building is shown in Fig.5.

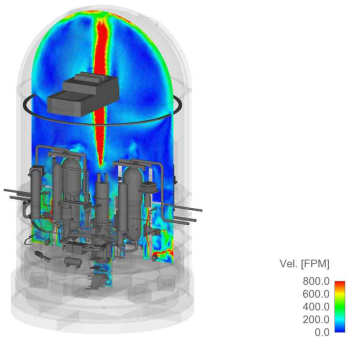
Complex flow patterns are found inside the reactor containment building. The temperature of the air passing through near the heating equipment is raised and the air supplied through the AHUs is circulating over the entire containment building.



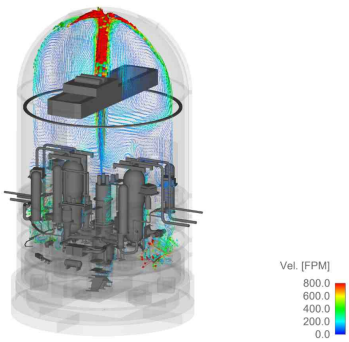
(a) colored by velocity



(b) colored by Temperature
Fig. 3 Streamline



(a) velocity distribution



(b) velocity vectors
Fig. 4 Velocity distribution and vectors

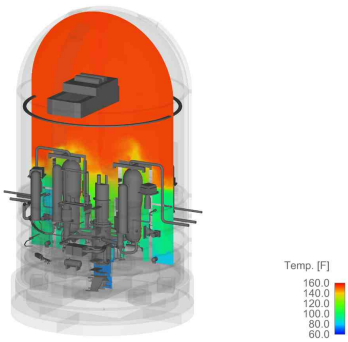


Fig. 5 Temperature distribution

6. Conclusions

In this study, CFD preliminary analysis has been performed to obtain the detailed information of the reactor containment building by using the CFD analysis techniques and to ensure that such information can be obtained via CFD analysis. We confirmed that CFD analysis can offer enough detailed information about flow patterns and temperature field and that CFD technique is a useful tool for HVAC design of nuclear power plants

REFERENCES

[1] FLUENT Manual