Heat Transfer and Impact Load of Steel and Concrete Double Containment

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1. Introduction

A preliminary analysis of thermal hydraulic and impact load performance of "steel and concrete" double containment has been performed. To evaluate steam condensation performance of air-cooled "steel and concrete" double containment vessel, A CFD (Computational Fluid Dynamics) analysis technique was applied. The impact load on the concrete wall by aircraft and thermal heat release rate by steel containment were evaluated. In this study, an inside concrete containment and outside steel double containment model was considered. The water thank is located between steel and concrete containments. The outer steel containment is cooled by air.

2. Numerical Model

The interior main components of containment such as reactor vessel, steam generators, crane, pipes, and other structures in Fig. 1 were excluded in the simulation model.

Containment models :
- Case(1) : Concrete
- Case(2) : Concrete + Steel
- Case(3) : Concrete + Steel + Water Tank

The compositions of containment in the three models are as following;

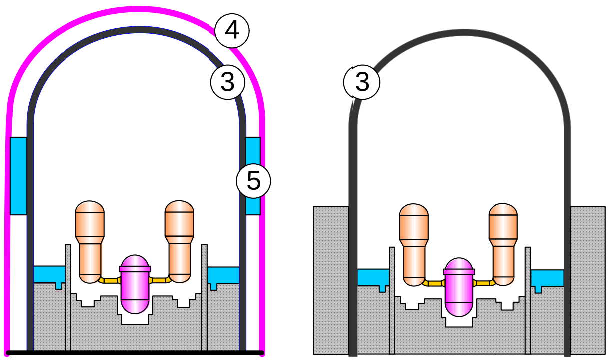
-Concrete Wall (Fig. 1, component No.3)
- Thickness : 1.5 m
- Outer Diameter : 24m
- Height : 81.6 m

-Steel Wall (Fig. 1, component No.4)
- Thickness : 15 cm
- Outer Diameter : 28m
- Height : 82.6 m

- Water Tank (Fig. 1, component No.5)
- Cooling Fin Height : 20 cm
- Cooling Fin pitch angle : 5 degrees

For the analysis of thermal hydraulic phenomena in a containment, CFX code was used. For the impact load analysis, the striking of Boeing 747-700 to the containment at 160 m/s was assumed. The impact load is evaluated at the outer surface of the concrete containment only for all the above 3 models. Figure 2 shows the aircraft impact model and Fig. 3 shows the composition of "Steel+ Concrete" double containment. The component No, 4 represents the outer steel containment.

For analysis of collision, the commercial code ANSYS AUTODYN V15.0 was used, and all parts except for cooling water tank was generated with Beam, Shell, and Solid element which were suitable for their individual shapes. However, for the cooling water tank, SPH element was used.



(a) "Steel+ Concrete" (b) Single concrete
Fig. 1 "Steel+ Concrete" double containment

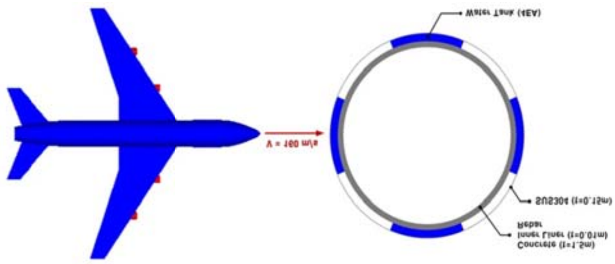


Fig. 2 Aircraft impact model

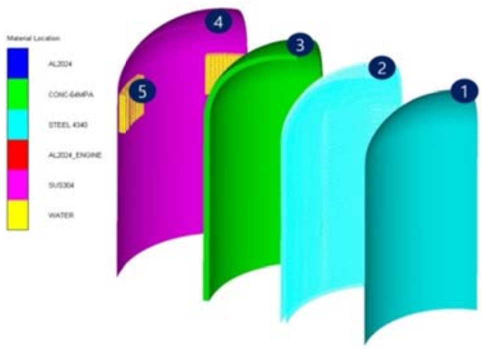


Fig. 3 Composition of "Steel+ Concrete" double containment

3. Calculation Results

Figure 4 shows the induced velocity distribution by CFX code analysis for a natural convection cooling flow. Figure 5 shows the induced velocity distribution by a cross cooling flow without cooling fin on the outer steel containment. Fig. 6 shows the induced velocity distribution by a cross cooling flow with cooling fin on the outer steel containment.

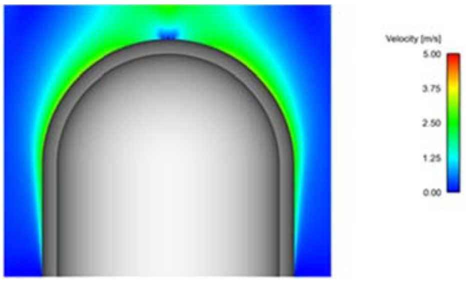


Fig. 4 Velocity distribution by natural convection

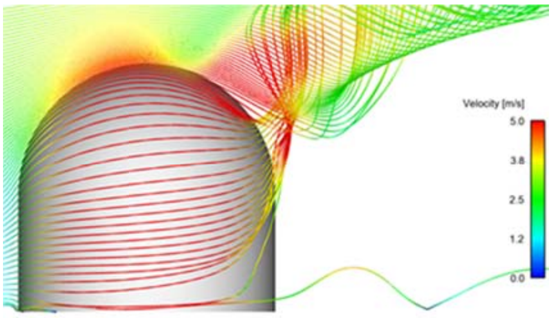


Fig. 5 Velocity distribution by Cross Flow without Cooling Fin

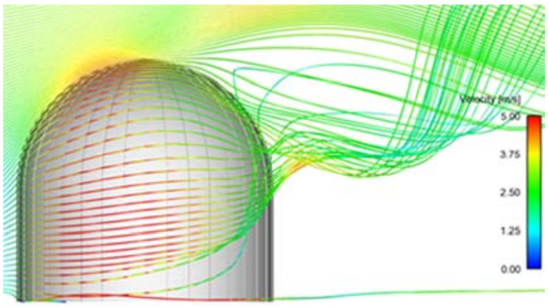


Fig. 6 Velocity distribution by Cross Flow with Cooling Fin

Table 1. Steam condensation rates

Type	Air Condition		Steam Pressure	Conden-sation Rate
	Temp.	Velocity		
N/C	30℃	-	3.0bar	3.458kg/s
Cross Flow	30℃	3.0m/s	3.0bar	4.029kg/s
Cross Flow	30℃	3.0m/s	6.0bar	5.647kg/s
Cross Flow	30℃	5.0m/s	6.0bar	7.017kg/s

Calculated steam condensation rates are summarized in Table 1

In case of the cross flow without cooling fin, the steam condensation rate inside the steel containment was 7.017 kg/s for the outside air velocity of 5.0 m/s and steam pressure of 6 bar.

In case of the cross flow with cooling fin of 20 cm height and pitch angle of 5° on the outside of steel containment, the steam condensation rate at the steel containment was about 8.24 kg/s. It is increased by about 17.4 % when compared to that of no cooling fin. This is about 43 % of the target steam condensation rate of the steel containment. If the shape, height and the interval of cooling fin are optimized, the steam condensation rate could be increased further more.

Figure 7 shows the impact load. The impact load for Case 3 containment is bout 40% when compared to that of single concrete containment (Case 1). The impact load of aircraft was transferred to the momentum of water particles of the cooling water tank.

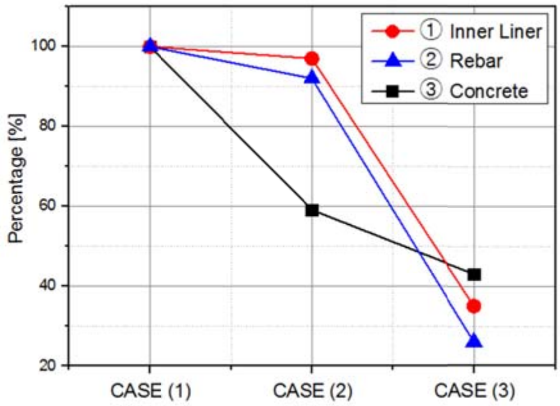


Fig. 7 Impact load by aircraft

4. Conclusions

Through the analysis, we could confirm the impact alleviation performance of SUS containment vessel and cooling water tank. They were devised in the stage of design concept of PCCS with the water-cooled and air-cooled double containment vessel. From all the results we could confirm the structural role of added structure, and in conclusion, the case of adding cooling water tank to SUS containment vessel could obtain bigger impact load dispersion effect.

Acknowledgement

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References

(1) Kwon, T. S. et al., "Report of impact load analysis for steel concrete double containment", KAERI-SBO-2016-011, 2016