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Feasibility Study to Reduce Thermal Resistance of Finned Containment Wall in Simplified OPR1000

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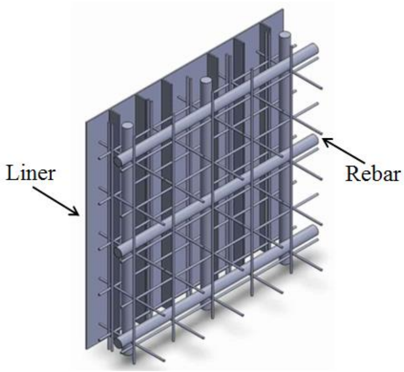
1. Introduction

After the Fukushima accident, securing the decompression and coolability of containment in the prolonged accident is one of the main issues. Commonly, the Containment Spray System is used for achieving decompression of containment in case of PWR (Pressurized Water Reactor) [1]. In addition to this, many nuclear power plants have been installed decompression equipment such as CFVS (Containment Filtered Venting System) and PAR (Passive Autocatalytic Recombiner) [2]. But these systems can't appropriately respond in case of long term accident. In these reasons, finned containment was proposed in the present work. The main idea is that the containment building is used as heat sink. This concept is securing of cooling capability by using finned containment itself, it could be another alternative for achieving decompression of containment as heat sink. The objective of this study is a feasibility test to estimate the heat transfer performance from the finned containment wall in case of OPR1000.

2. Configurations of Test Containment Building

Table I: Dimensions and properties of the components of containment building tested in the present work

Component	Internal fin	Internal liner	External fin	External liner	Rebar	Wall
Material	Steel	Steel	Alloy 2014-T6	Steel	Steel	Concrete
Dimension (mm)	30T	6T	30T	6T	50D 250D	1200T
Density (kg/m^3)	7850	7850	2770	7850	7850	2330
Thermal Conductivity (W/m·K)	47	47	177	47	47	1.6
Specific heat capacity (J/kg·K)	503	503	875	503	503	645



(a) Typical liner and rebar configuration of reinforced-concrete in OPR1000

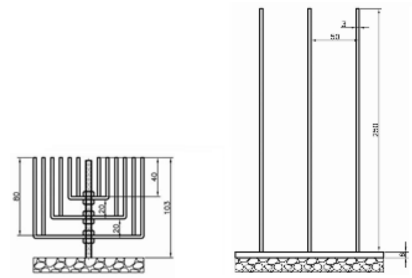
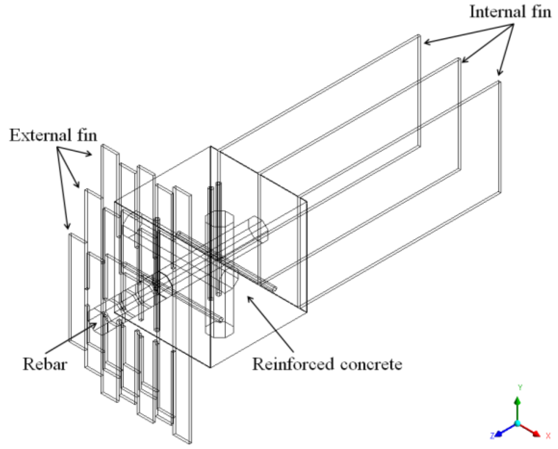

(b) External fin (c) Internal fin

Fig. 1. The test fin geometries of containment building in the present work

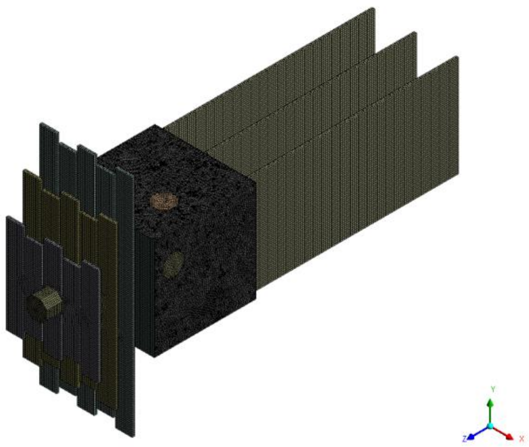
Figure 1 shows the geometry of the simplified containment wall of OPR1000 tested in the present work. The thickness of the reinforced concrete structure is 1.2m. The calculation domain of the present numerical simulation is 1.2m x 1.2m in its cross section. The external aluminum fins are attached to the rebar and the internal fins are welded to the inner liner as shown in Figure 1. The internal steel fins are vertically installed as 0.5 m intervals. The thicknesses of the external and internal fin are 0.03 m. The dimension and properties of fins are listed in Table I.

3. Numerical Simulation

The calculation domain and numerical grid of the present work are shown in Figure 2. The commercial code, ANSYS CFX 16[3] was used in this work. The number of grids is about 1.8 million. Conduction equation in the steady state was solved for the domain, the convective heat transfer boundary conditions were applied for the fins and wall surface as shown in Table II. Boundary conditions were given to the heat transfer coefficient based on the severe accident conditions. External heat transfer coefficient is 11W/m^2·K in case of concrete surface at 2.8m/s based on average wind velocity of Wolseong NPP. Internal temperature of containment building is 422K based on the limitation temperature of 10CFR 50.34.



(a) Calculation domain



(b) Numerical grid

Fig. 2. Numerical domain and grid in the present work

Table II: Test conditions of containment wall in the present work

Component	Internal interface	Reinforced-concrete connection interface	External interface
Material	Water vapor-Air mixture	Steel Concrete	Air
Reference temperature (K)	417	Average temperature	288
Heat transfer coefficient (W/m^2·K)	795	7850	17
Reference pressure (atm)	3.95	-	1
Analysis condition	Constant heat transfer coefficient	Periodic	Constant heat transfer coefficient

Table III: Geometric conditions of numerical simulation in the present work

Type	Geometric conditions
Present containment wall	All embedded reinforced
Finned containment wall A	Present + 50D steel bar + fin
Finned containment wall B	Present + External liner + 250D steel bar + fin

4. Results and Discussion

The temperature distribution on the center cross-section of the reinforced concrete was shown in Figure 3. Moreover, the temperature distribution is low gradually because of conduction from the inner wall to the outer wall of the concrete. The temperature gradient of (a) is almost same with that of (b) in Figure 3. Rebar has high conductivity than concrete. Therefore, 250mm rebar affects more considerable than that of 50mm to the temperature distribution. For this reasons, temperature distribution of z-axis direction was showed significant changes in (c).

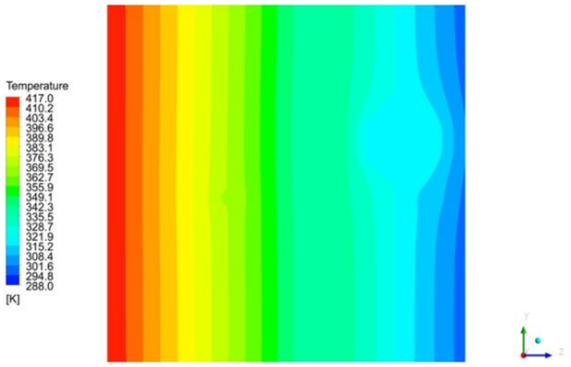
The heat transfer in three types of containment was 267.6W, 265.2W and 307.8W, respectively. The Type B case increased up to 15% of heat transfer than the baseline containment building. The thermal conductivity of the steel is higher than concrete about 29.4 times, and heat transfer was increased with increasing cross-sectional area of rebar. The numerical simulation shows that the fin efficiency of the present external fin is very low as 3.1%.

5. Conclusion

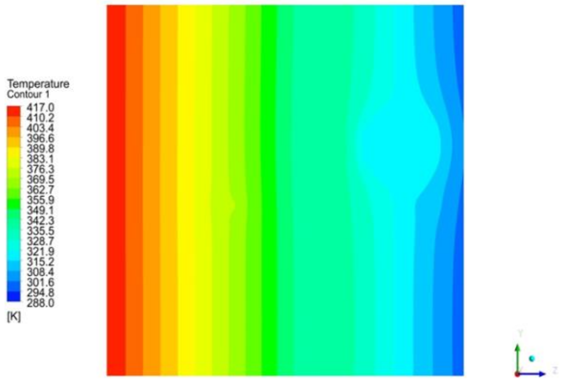
Three different types of containment wall were tested by numerical simulation to understand the cooling performance of finned containment wall. We can conclude as follows:

For the finned containment wall type A that fins are installed inside and outside with the same rebar configuration of conventional containment building, the heat transfer is almost the same as conventional containment wall. The finned containment wall type B that volume fraction of rebar is increased transfer the heat 15% more compared with conventional one. The cross-sectional area or volume fraction of the rebar to attach fin is important to enhance the heat transfer. The fin efficiency of the fin is very low as 3.1% in the present cases.

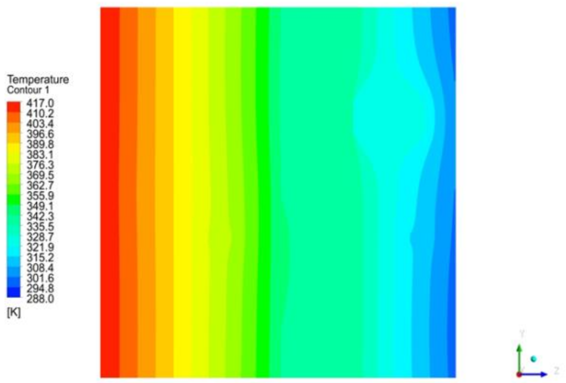
Further studies are necessary to design in consideration of the rebar and the fins comprehensively in order to find the optimum configuration.



(a) Present containment wall



(b) Finned containment wall A



(c) Finned containment wall B
Fig. 3. Isotherm lines of the center cross-sectional area of concretes areas in the present work

Acknowledgements

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REFERENCES

[1] USNRC, “Pressurized Water Reactor (PWR) Systems”, Reactor Concepts Manual
[2] Y.M. Song et al, “Overview of Containment Filtered Vent under Severe Accident Conditions at Wolsong NPP Unit 1”, Nuclear Engineering Technology, 2013
[3] ANSYS Inc., “CFX 16”, Training Manual