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Analysis of Thermal Behavior in a Cargo Hold of LILW Transport Ship

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1. Introduction

With determining Kyongju as a repository site for the low and intermediate-level radioactive waste (LILW), it is time to decide transportation method to bring the waste from NPPs (Nuclear Power Plants) to the site. Now considering transport ship as an alternative, it is important to design cargo compartments in the ship. Especially, it is necessary to ensure thermal criteria in the cargo hold by using natural or forced convection [1]. According to INF Code, there is addressed a technical standard of the cargo that adequate ventilation or refrigeration of enclosed cargo spaces shall be provided so that the average ambient temperature within such spaces does not exceed 55℃ at any time [2]. And many counties which operate LILW transport ships are conformable to the standard [3], and Ministry of Maritime Affairs and Fisheries of Korea also follows it. In this article analytical study of ventilation system in a cargo hold shows to keep the temperature below 55℃ or not.

2. Analysis and Results

There is a possibility of heating-up in the cargo hold due to continuous irradiation from the sun though decay heat from wastes carried by LILW transport ship is negligible. Thus, in this section analytical method used to model a cargo hold in the LILW ship is described. The analysis tool is a computational fluid dynamics code, FLUENT, and 3-D modeling technique was allowed.

2.1 Description of the cargo hold

Figure 1 shows a schematic of the LILW transport ship. There are four cargo compartments and each compartment have two ventilation sets (two Flow-ins and two Flow-outs). Specifications of the ventilation systems are listed up in Table 1.

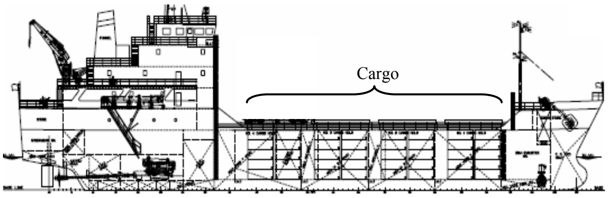

Figure 1 Schematic of LILW transport ship

The cargo compartments are numbered from No.1 toward the front of the ship to 4. The cargo compartment No. 2 to 4 have the same volume and ventilation systems but cargo No. 1 has different geometry and systems. In this study the cargo No.1 was considered for thermodynamic analysis.

Cargo No.	Ventilation System	Size	Number	Remark
1	Flow-in	50m³/min × 20mmAq fan w/ mushroom	2	axial flow type sup(rev) type
	Flow-out	250Φ mushroom vent	2	JISF 2407 BA-250
2, 3, 4	Flow-in	50m³/min × 20mmAq fan w/ mushroom	2	axial flow type sup(rev) type
	Flow-out	450 Φ mushroom vent	1	JISF 2407 BA-450

Table 1 Ventilation systems in the cargo hold

Each cargo hold has the hatch cover of 140 mm concrete which is lapped with 10 mm stainless steel. There are two mushroom typed ventilation holes of 250 mm in diameter and two motored-fan mushroom holes which are actuated automatically by thermal sensor. The cargo hold would keep the inner temperature below 55℃ by natural convection through the two flow-outs, but if the temperature goes up to the limit due to continuous heating-up from the sun in summer season, forced convection by the electric fan would descend the inner temperature.

2.2 Analytical Modeling

The Figure 2 shows three-dimensional configuration covered with the hatch cover and analytical nodalization model for FLUENT simulation. CFD code FLUENT is a well-known analytical tool used comprehensively in three-dimensional thermo- and fluid-dynamics analysis.

The number of total calculation cells is about 165,000, which is generated in hexagonal mesh form by a preprocessor of GAMBIT. The hatch cover area, in which major heat transfer mechanism is conduction, was simulated by 15,466 calculation cells and the volume of

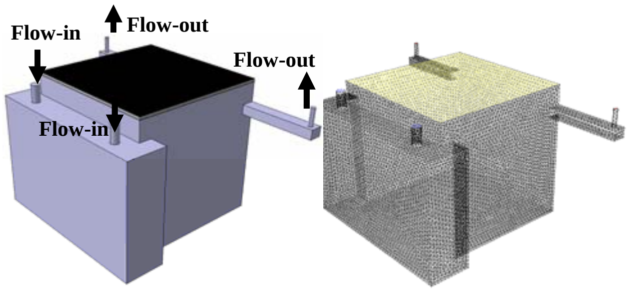

Figure 2 Analytical model and nodalization for 3-D FLUENT analysis

the cargo hold, in which convection heat transfer is dominant mechanism, was modeled by 148,938 hexagonal nodes.

2.3 Initial and boundary condition

For comprehensive study under various conditions against severe accident cases in navigation, two cases were considered in this study but just a reference case was investigated in this article. The reference case covers the atmospheric and near sea condition of domestic southern region. In disregard of heat transfer from the side walls of the cargo hold, even it is assumed that there is no decay heat from the waste in the compartment. That is, it means the heat source irradiated on the hatch cover from outside atmosphere comes from only the sun. The initial temperature of the air in the compartment free volume is assumed to 38℃, which is nearly high temperature at noon in summer season. And atmospheric air temperature around the hatch cover is also 38℃. Heat dose rate from the sun is referred as 0.3 times of solar constant (2.0 cal/m^2min), which is heat rate per unit area, because some amount of the heat from the sun is reflected into atmosphere. Heat absorption mode on the hatch cover is assumed as a black body radiation. Consequently, total amount of heat rate supplied on the hatch cover is about 540.6 W/m^2.

2.4 Analytical results

Figure 3 shows temperature distribution contour after 1.5 and 3 hours in the compartment. One electric fan was actuated after 3 hour as time goes on and after 1.5 hour (total 4.5 hour) the other electric fan was in operation. Though the temperature in cargo hold reaches locally 55℃ in 1.5 hour, the average temperature keeps it below as shown in Figure 3.

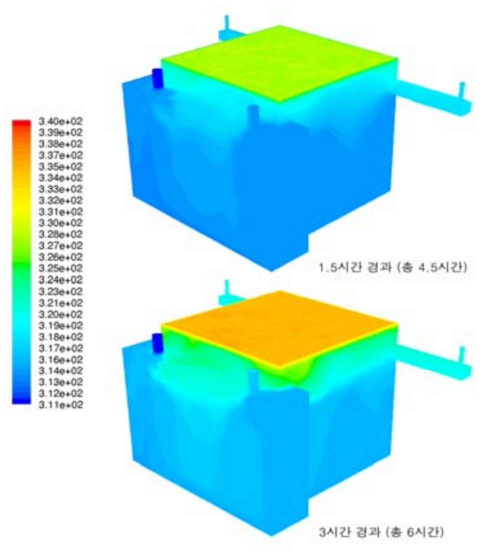

Figure 3 Temperature contours in 1.5 and 3 hours

These phenomena also address the average temperature is maintained below 55℃ in total 6 hours. Thus, we can conclude that the ventilation system in the cargo hold meets the design criteria.

Figure 4 shows flows patterns in vector and flow line that outside air from the Flow-in hole flows through the Flow-out hole and the Flow-in hole which is not in operation.

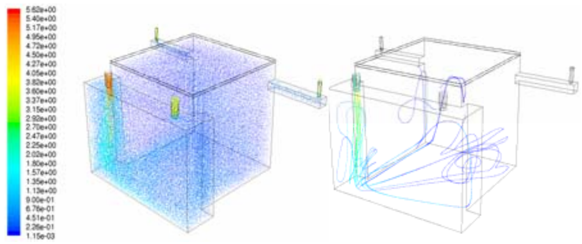

Figure 4 Flow vector and line in 1.5 hour

Temperature distributions with time transient of the air in the cargo hold are shown in Figure 5. As shown in the figure, the average temperature is blow the limit by far.

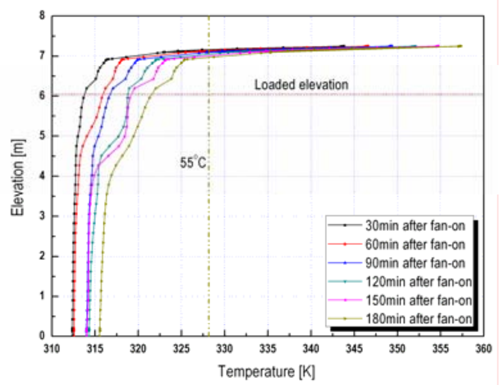

Figure 5 Temperature distribution with time transient

3. Conclusion

Thermal behavior in the cargo compartment due to gradual heat-up from the sun onto the hatch cover of the LILW transport ship was investigated and it's result shows that the designed system for the cooling ventilation in the cargo compartment is very effective to meet the technical standard, considering atmospheric condition of the southern region in Korea

REFERENCES

[1] Regulations for the Safe Transport of Radioactive Material, IAEA, TS-R-1 (ST-1, As Amended 2003)

[2] International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on Board Ships (INF Code), IMO, 2000 Edition

[3] Kaisa No. 450, Special Safety Requirements for Ships Carrying Low Level Radioactive Material, Ministry of Transport, Japan, 1988