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Validation of FDS5 Simulation for Postulated Fire in a Day Tank Room

JongSeuk PARK*, YoonJeong PARK, ChangJu LEE
KINS, Gwahak-ro 34, Yuseong-gu, Daejeon, Korea, 305-338
**Corresponding author: park@kins.re.kr*

1. Introduction

The use of computer fire model has been dramatically increased due to a rapid development of computer hardware and numerical scheme as well.

NFPA 805 [1] requires fire models to be verified and validated against the geometric complexity of analysis regime and range of features in the models. To meet the requirement, US NRC along with EPRI and NIST had conducted an extensive verification and validation (V&V) study of fire models, which support the use of NFPA 805 [2]. NUREG-1824, which is based on ASTM E1355, is the product of the above V&V study.

Verification and validation of a calculation method is intended to ensure the correctness, suitability and applicability of the method.

The fire load of a day tank room of emergency diesel generator building is relatively very high compared to that of the other compartments in a nuclear power plant (NPP).

This study is intended to validate the FDS5 (Fire Dynamics Simulator Ver.5) simulation results of a postulated fire at a typical day tank room of emergency diesel generator building in NPPs.

2. FDS5 simulation of a day tank room fire

The FDS5 is most widely used to simulate the compartment fire. FDS5 simulates the computational regime with a numerical form of the Navier-Stokes equations, which are appropriate for the low speed and thermally-driven buoyant flow with an emphasis on smoke and heat transport from fire [3]. The LES turbulent model was used in combination with the Smagorinsky sub-grid model.

The total volume of analysis regime is 7.2x13.5x5.0 (m^3) and the volume of each day tank room is 3.8x3.8x5.0 (m^3). The geometry of compartments was nodalized with the number of cells of 36x64x24 with each cube size of 0.2 m. Fig. 1 shows the FDS5 modeling result of a day tank room.

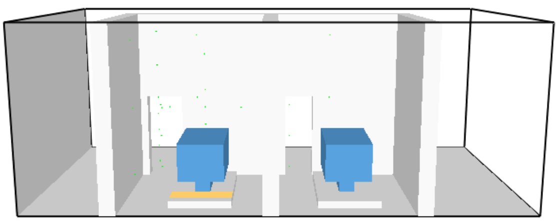

Fig. 1. FDS modeling of day tank room

2.1 Fire scenarios

The following assumptions were used in this study; a) the fire doors are opened for the maintenance during the overhaul period and the diesel oil is spilled through the bottom of day tank and has formed a pool in a tank supporting plate. b) The total weight of spilled diesel oil is 151 kg with pool area of 1.08 m^2 and the source of a fire may be ignited in the oil pool spilled from a day tank. The heat release rate (HRR) per unit area is calculated as a 1630 kW/m^2 using the thermal properties of diesel oil in Table 1.

Two fire scenarios were considered for; a) a fully opened fire door, b) a 40% opened fire door. Table 2 lists the locations of temperature measurement.

Table 1. Thermal properties of diesel oil

Parameter	Value
Heat of combustion	43100 kJ/kg
Mass loss rate	0.039 kg/m2-sec
Efficiency of combustion	0.97

Table 2. Temperature measurement locations near door

Variable	Elevation
door1_t1	0.2 m
door1_t2	1.2 m
door1_t3	2.2 m

2.2 Temperature distribution of room

Fig. 2 and 3 compares the average temperature at the upper layer and the lower layer in the fire room. The average temperature distribution in the fully opened case is much different from that of the 40% opened case. It means that the opening rate of fire door has a significant impact on the air flow through a door and thus the fire growth.

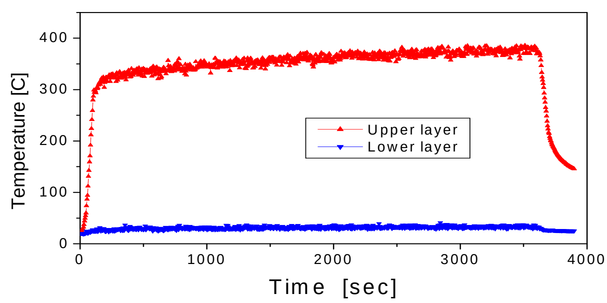

Fig. 2. Fire room avg. temperature at fully open case

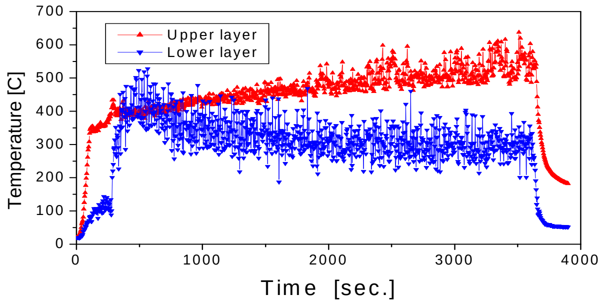

Fig. 3. Fire room avg. temperature at 40% open case

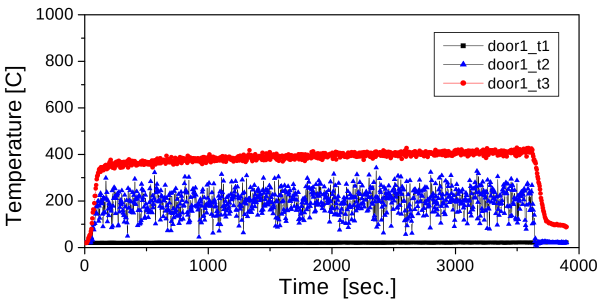

Fig. 4 Temperature near door at fully open case

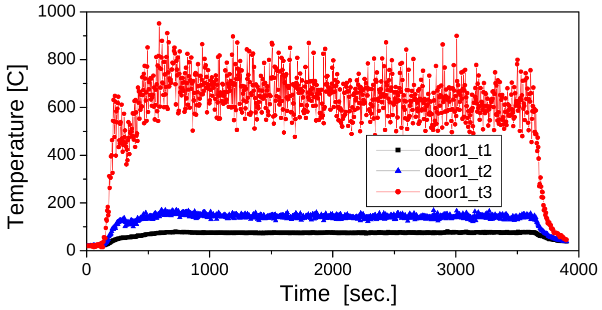

Fig. 5 Temperature near door at 40% open case

Fig. 4 and 5 show the temperature profiles of the simulated scenarios (see Table 2). The temperature fluctuations in the middle point of the door are larger than those of the upper and lower points in the fully open case. But the temperature fluctuations at the upper point of the door are much larger than those of the middle and lower at 40% open case. It means that the shape of air flow and flame spread is completely different between the fully opened case and the 40% opened case.

It is shown that the opening status of the fire door in multi-compartment fire has significant impacts on the inside temperature and the flame developments as well.

3. Validation of FDS simulation

The NUREG-1824 describes that the applicability of the validation results can be determined using normalized parameters, which are traditionally used in fire modeling applications[4]. The normalized parameters selected in NUREG-1824 are; HRR, Room/Target height, Ceiling jet radial distance, Radiant heat flux, and Natural/Mechanical ventilation.

Table 3. Summary of validation results

Normalized parameter	Validation range	Values in this study
HRR	0.4 ~ 2.4	1.08
Room/Target height	3.6 ~ 16	4.2
Ceiling jet radial distance	1.2 ~ 1.7	N/A
Radiant heat flux	0.03 ~ 0.2	N/A
Room size - W/H	0.6 ~ 5.7	0.76
- L/H	0.6 ~ 2.0	0.76
Natural / Mechanical ventilation	0.04 ~ 0.6	0.52

Among the above normalized parameters, the ceiling jet radial distance and radiant heat flux were not applied to this study since the target near ceiling was not simulated. Details of all those normalized parameters are described in Table 2-4 and Table 2-5 of the NUREG-1824, vol. 1.

Table 3 summarizes the simulation results of the normalized parameters. It is confirmed that all the applied normalized parameters are well within the validation ranges.

4. Conclusions

FDS5 simulations were performed for a postulated fire in a day tank room. As a result, it is identified that the opening status of fire door in multi compartment room should be considered as an important sensitivity parameter.

The validity of this simulation results was demonstrated by confirming that the normalized parameter values are well within the validation ranges given in NUREG-1824.

REFERENCES

[1] National Fire Protection Association, "Performance-Based Standard for Fire Protection for Light-Water Reactor Electric Generating Plants," NFPA 805, Sections 2.4.1.2.2 and 2.4.1.2.3, 2001.

[2] M.H. Salley, et al., "Verification and Validation – How to Determine the Accuracy of Fire Models", FPE magazine, pp 36, spring, 2007.

[3] K.B. McGrattan, et al., Fire Dynamics Simulator (Ver. 5), Technical Reference Guide, NIST Special Publication 1018-5, NIST, Gaithersburg, Maryland, USA, 2007.

[4] US NRC, "Verification and validation of Selected Fire Models for Nuclear Power Plant Applications," NUREG-1824 Vol. 1, pp 2-25, May 2007.