FDS5 Simulation for OECD PRISME Fire Test of DOOR PRS_D5

Kyu Bok Lee[a*], Park, JongSeuk[b]
[a]*Korea Power Engineering Company, Inc., 360-9 Mabuk-dong, Giheung-gu, Yongin-si, Gyeonggi-do*
[b]*Korea Institute of Nuclear Safety 19 Guseong-dong, Yuseong-gu, Daejeon, Korea, 305-338*
[*]*Corresponding author: kblee@kopec.co.kr*

1. Introduction

OECD/NEA PRISME Fire Project is an international co-operation project to investigate fire propagation by means of experiments and analyses for nuclear power plant applications. This project focuses on the generation of experimental data for fire and smoke propagation from the fire room to adjacent rooms under various conditions and room configurations. In addition, analyses using computer codes are performed to understand the phenomena of interest and to produce a consistent interpretation of the experimental results. The PRISME Project is composed of series of tests named as SOURCE, DOOR, LEAK and Global Tests. The SOURCE is composed of tests to characterize the fire source, and the DOOR is to study fire and smoke propagation through an open door, while the LEAK is to investigate hot gas leakages through other modes of openings such as holes, a slot, a duct, and a partially-opened door. The Global test will be conducted as integral tests on the basis of the results of the previous separate effects tests. In this paper, simulations are performed with FDS5 computer code for the DOOR Test No.5 (PRS_D5) and the calculation results are compared with the corresponding experimental data to study the code capability to predict the phenomena of the hot gas propagation between two rooms.

2. Test Description

The PRISME DOOR Test is to study the heat transfer mechanisms of hot gases and smoke from a source room (fire room) containing the fire source towards a target room by natural convection mode, i.e. through a door completely open between rooms. This experiment consists of six tests based on the variation of three main parameters: the fire pool area, the air change rate and the number of rooms involved [1]. The fuel is hydrogenated tetra-propylene (TPH) and contained in the fuel pan located at the center of the fire room. The experiment is carried out in the DIVA facility in IRSN as shown in Figure 1 [2]. Cables and PVC rods are placed on cable trays in the rooms as thermal targets.

Of the DOOR Tests, the test no. 5 involves only two rooms, i.e. fire room and target room. Each room has the size of 5m(L) x 6m(W) x 4m(H). Also, the PRS_D5 test is performed for the fire pool surface area of $1m^2$, the fuel mass before ignition of 15.902 kg and the mean initial air renewal rate of $4.75h^{-1}$ [3]. The key parameters are measured during test to characterize the hot gas propagation phenomena between two rooms.

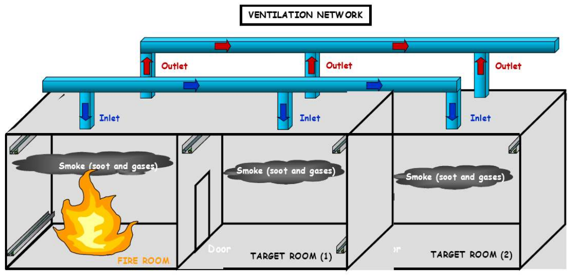

Figure 1. Room Configuration for DOOR Tests

3. FDS5 Modeling

The Fire Dynamics Simulator (FDS) is a computational fluid dynamics model of fire-driven fluid flow. FDS solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flow with an emphasis on smoke and heat transport from fire [4]. The hot gas propagation of the PRS_D5 test is modeled with FDS5 version 5.1.0. The geometry of the rooms is nodalized with the number of cells of 108 x 64 x 45 which results in the each cell size of 10cm x 10cm x 10cm. The ventilation rate of the room is fixed as $570m^3/h$ during the whole simulation, and the radiative fraction and soot yield rate of the fire source is set to 0.35 and 0.01, respectively, as default values built in the codes. The heat release rates (HRR) of the fire source obtained from the experiment are slightly modified to use as input of the FDS5, as shown in the Figure 2.

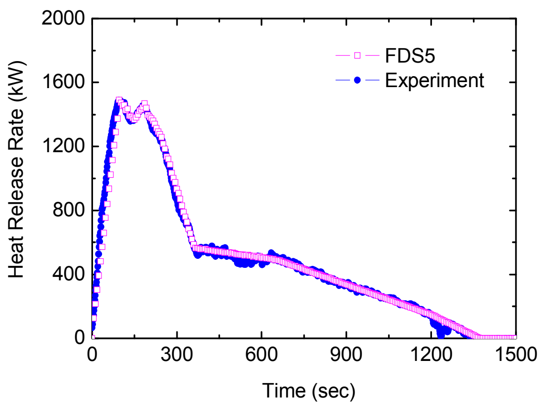

Figure 2. Heat Release Rate of PRS_D5 test

4. Calculation Results

Calculations are performed with FDS5 to generate parameters characterizing the fire propagation between two rooms, and the results are compared with their experimental data to assess the code capability to predict the fire phenomena. The calculated parameters include gas temperatures in each room, heat fluxes and temperatures of the walls and the cable targets, gas velocities between two rooms, concentrations of the combustion products such as O_2, CO_2 and soot.

Figure 3 shows the gas temperature at the top of the north-west side of the fire room. At this point, the temperature rises up to about 500℃ in the experiment. The overall trends of the FDS5 calculations are similar to those of the test data, even though the peak temperature is under-estimated by about 20%.

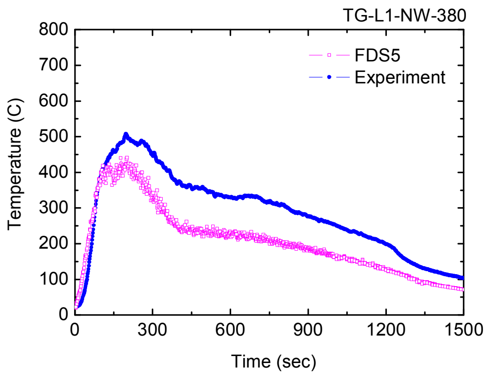

Figure 3. Comparison of Temperature at the North-West Side of the Fire Room

The comparison of the temperature at the top of the center of the target room is presented in Figure 4. Similar to those of the fire room, the calculations with FDS5 are close to the experimental results. These comparisons imply that the FDS5 has enough ability to simulate the hot gases propagation to the adjacent room and to predict the temperature distribution in rooms.

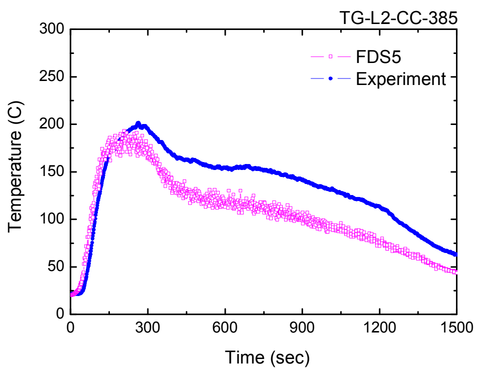

Figure 4. Comparison of Temperature at the Center of the Target Room

Another comparison is shown in Figure 5 for the cable target temperature located at the upper part of the fire room. Contrary to the room temperature, the target temperature shows differences between the calculations and the experiments. As seen in this figure, FDS5 generates lower temperatures than those of the test. The peak value of the calculation is equivalent to the 47% of the experimental data.

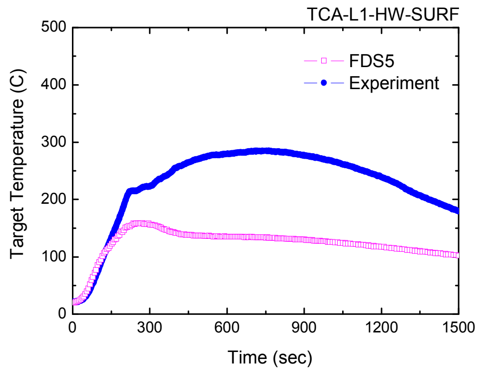

Figure 5. Comparison of Cable Surface Temperature at the Upper Side of the Fire Room

From other comparisons, some discrepancies between the calculations and the experiments are also observed for some values such as CO_2 concentration, heat fluxes and temperatures of the wall and the target. In addition, the differences are generally larger in the fire room than in the target room.

5. Conclusions

Simulations are performed with FDS5 computer code for the DOOR Test no.5 and the calculation results are compared with experimental data to study the capability of the code. From the comparisons, it can be concluded that the FDS5 has sufficient ability to simulate the increase of the room temperature. However, some discrepancies are also observed for some values such as CO_2 concentration, heat fluxes and temperatures of the wall and the target. Therefore, further works are to be needed to investigate the reasons of the differences. The additional studies may have to include the detailed modeling of the ventilation network, the sensitivity studies for the parameters such as the cell size, radiation fraction and soot yield rate. Also, the comparisons with other types of tests have to be included in the studies to successfully apply the FDS5 to the real fire simulation of the nuclear power plants.

REFERENCES

[1] W. LE SAUX, "PRISME DOOR Programme – Analysis report," DPAM/SEREA-2008-157-PRISME 26, IRSN, 2008.
[2] W. LE SAUX, "Description of the DIVA facility," DPAM/SEREA-2006-157-PRISME 2006-008, IRSN, 2006.
[3] W. LE SAUX, "PRISME DOOR Programme – PRS_D5 test report," DPAM/SEREA-2007-085-PRISME-021, IRSN, 2007.
[4] Kevin McGrattan, et al., "Fire Dynamics Simulatior (Version 5) User's Guide," NIST Special Publication 1019-5, NIST, 2008.