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Application of CFAST in Warehouse Fire Simulation

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ABSTRACT: *In this paper, Consolidated Fire and Smoke Transport (CFAST) zone fire model is used for the calculation of temperature, smoke volume and its location from a compartmental fire developed in a book warehouse, where books kept on racks acts as a fuel for the propagation of fire. In this simulation, the two compartments modelled were divided into layers representing the upper as well as the lower zone of the room in which the variation can take place between the floor and ceiling only. Inside the compartments the fire source position lies at the position of racks, CFAST showed very high temperatures. The simulations have also been carried out by using 3 different strategies in which different fire safety measures were undertaken in the warehouse compartment. It was observed that location of racks in which fire propagates have an important role in the spreading of fire and smoke plumes.*

Keywords: **CFAST, Fire modeling, Zone model, Warehouse fire**

1. INTRODUCTION

A computational method in fire modeling plays an imperative role in protection against fire and building design engineering.In a global review of computational models for fire & smoke, 36 vigorously supported models were recognized [1]. From those 36 models, 12 were zone type models. Considerable increase in available fire models has been done over the last 10 years [2]. For distinct regions, zone model solves the conservation equations. The assumption taken in a zone model is that properties like temperature, smoke and gas concentrations can be approximated about entire zone by using some uniform functions. Experimental observations show that the uniform properties zone assumption yields good agreement [3].The zone method which have been developed and implemented for many years displays an added mature field for fire and smoke transport.

Consolidated model of Fire Growth and Smoke Transport (CFAST), was developed and released by BFRL (Building and Fire Research Laboratory) at the NIST as a computer code that is meant to assist research in the field of fire dynamics with minimum computational requirements for the prediction of fire in a structure. This computer code is also known as zone model code as it divides each room in two separate lumped-parameter volumes i.e cold lower layer and hot upper layer. In a two zone model, the fire that originates in lower region of a room entrain air into a smoke plume and transport heat and mass into the upper layer. [4]

There are total 11 variables which is to be solved in a zone model which are mass, internal energy, density, temperature and volume for the upper as well as lower layers, and the pressure P [5]. As we have 7 constraints, any 4of those variables have to be selected as solution variables which are the pressure above the reference value, volume of the upper layer, and temperature of upper and lower layer.

The main objectives are to:

(a) Illustrate the use of the CFAST simulation in the calculation of smoke produced by a fire in a two storey house.

(b) Determine the volume, temperature and location of the smoke in the warehouse compartment.

(c) Show calculations with standard zone modeling.

(d) Find the time for activation of smoke detectors in different rooms based on the criteria of local temperature reaching.

2. DESCRIPTION OF THE MODEL AND SIMULATION

For modeling, the stack room of warehouse is selected for software analysis and fire risk modelling. In the warehouse stack room there are lots of combustibles like papers and books which can cause and be the source of fire accident in room. It is assumed that fire starts with an electrical malfunction causing nearby rack lit up and the main fuel is made of cellulose ($C_6H_{10}O_5$) being the main ingredient of paper.

Table 1: Dimensions of room, window and door

Particulars	Dimensions
Room	19340x19090x3600 (mm)
Window (18)	1800x1800 (mm)
Door (assumed shut)	1800x2500 (mm)

The rack is kept at a distance of only 14 cm from switch board and wire connection, thus the books in vicinity catches the fire and thus may lead to flashover. The basic fire safety measures adopted in the simulation modeling using CFAST are

Proper ventilation system i.e. spacious room, windows at interval.

- Sprinkler system inside room.
- Mechanical venting system.
- Windows sill procurement.
- First aid firefighting tools.

CEdit tool is used for building the input file of CFAST, in which the first step was to create the basic geometry of the structure as shown in figure 1.Compartment size were taken from table 1.

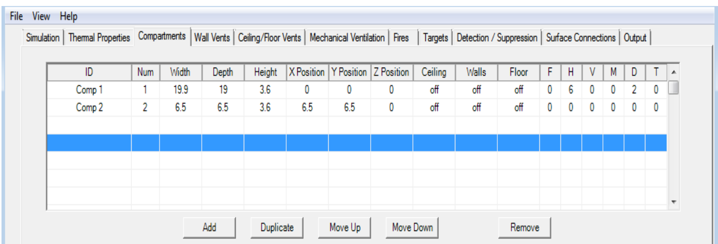

Figure 1: Input parameters for compartments of warehouse in CFAST

Figure 2 shows the input parameters for the fire source, in this case it is C6H10O5 (Cellulose) which is the main ingredient of paper. Four racks near the front vents were assumed to be under fire, on the basis of this four fire hotspots were created on different locations as shown in figure 2 and figure 6-8.

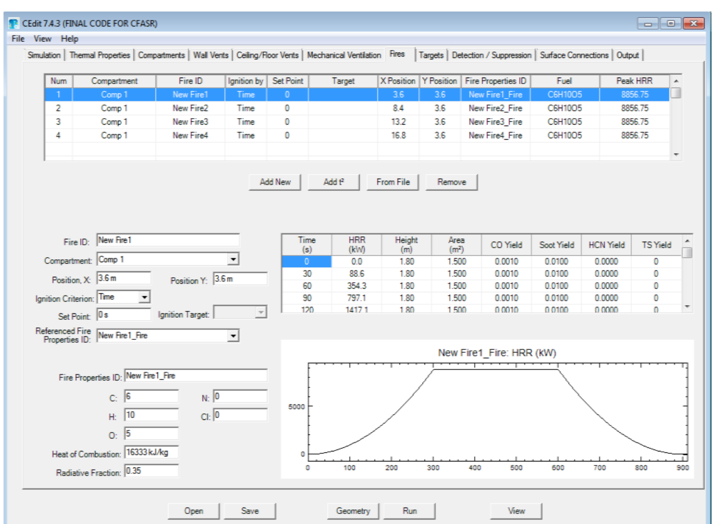

Figure 2 : Input parameters for fire source

Figure 3 shows the input properties of sprinkler and heat detector system, the location of sprinkler system is specified as shown in figure 3 along with its activation characteristics so that when the temperature reaches beyond it specified threshold value, it starts to spray water droplets in pre defined pattern.

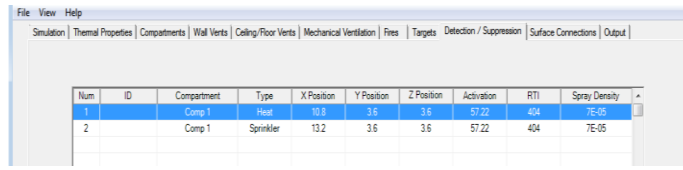

Figure 3 : Location of Heat detector and sprinkler in compartment 1

After feeding all the necessary data for the simulation, the next step was to run the geometry. The output clearly states that after 900s of simulation time the simulation stopped. The total execution time was 76.4 seconds and number of time steps was 1134. The sprinkler system got activated after 60 seconds of simulation run for dissipating the compartmental fire.

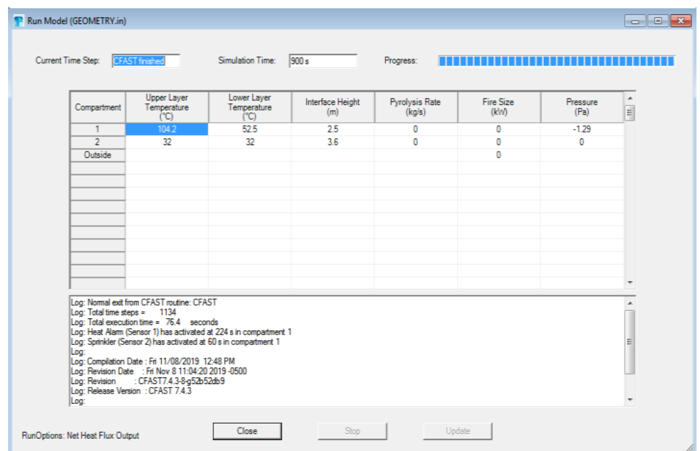

Figure 4: Simulation output from CFEST

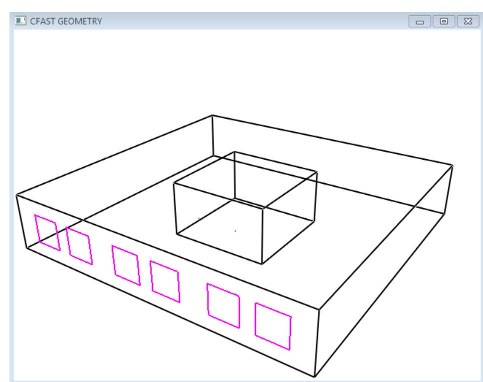

Figure 5: Outline of geometrical structure of warehouse compartments with vents

Figure 5 shows the outline geometrical structure of the warehouse compartments with vents, it was assumed that all the doors were shut for the simulation process and no other excavation activities takes place during this period as it was not possible to simulate all these simultaneously due to the restrictions in CFAST.

The fire safety measures formulated is most basic for any building safety. Thus the fire spread model will be easy to follow. So the framework is named as simulation output for analysis. Thus according to the safety measures given and fire modelling software's data, the simulation output is classified in four. They are

- Max untenable HRR.
- Flame spread over adjacent floors.
- Flashover occur in the room.
- Oxygen concentration

Since fire safety strategies basically deals with the safety of person and control of physical damages, thus the physical evidence are considered. This evidence is the data which directly affects the risk to people's safety. Though use of evacuation model is not considered in this work, therefore we can further use the physical aspects of fire. Accordingly, the fire safety strategies can be formulated on the basis of fire safety measures given previously. The strategies are categorized on the basis of data given in fire research journal [6] and are given below:

Table 2: Fire safety strategies

Strategy	Measure	Remark
A	1 &3	Corresponds to the initial level of fire safety in this warehouse (current fire safety measures).
B	1, 2, 3, & 4	Complies with building safety regulations for warehouse.
C	1, 2, 3, 4 & 5	Use of all safety measures as base level.

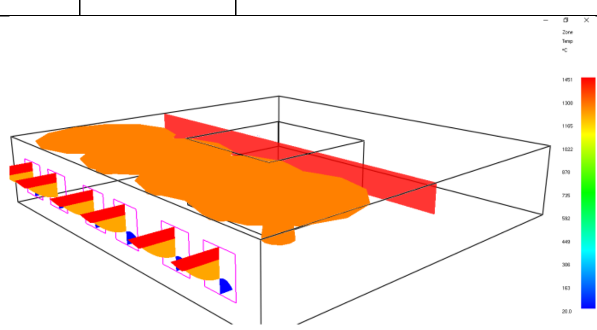

Figure 6: Fire simulation using strategy A

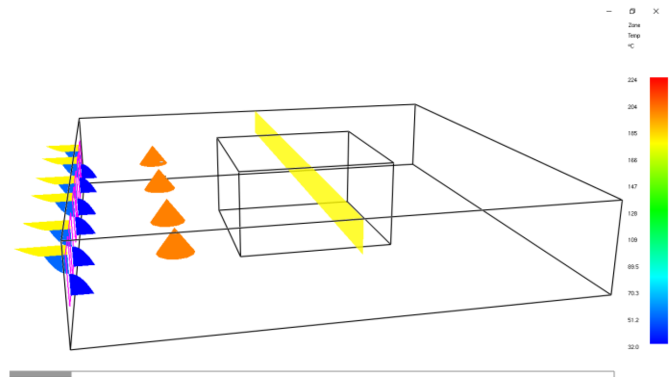

Figure7: Fire simulation using strategy B

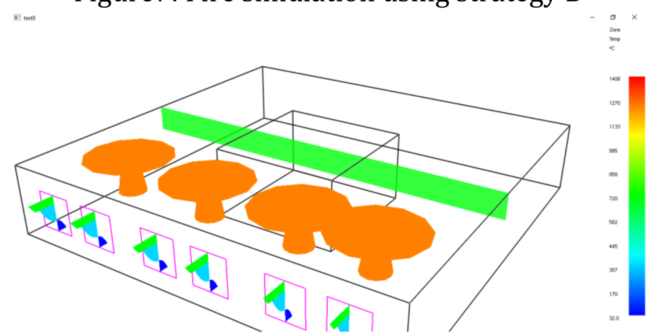

Figure8: Fire simulation using strategy C

3. SIMULATION OUTPUT

Simulation was performed for all the three fire safety strategies, the output of which is shown in figure 6 representing fire simulation for strategy A, figure 7 representing fire strategy B and figure 8 representing fire strategy C. The output of CFAST fire strategy simulations were accumulated and shown in Table 3 classified according to the safety measures as discussed in section 2.

Table 3: CFAST strategies simulation output

Simulation output	Strategies result		
	A	B	C
HRR	23987.43	15881.84	12132.41
Flame spread over adjacent floors	~	~	~
Flashover occur in the room	1	0	0
Oxygen % concentration at 120 sec	16.7	17.9	18.2

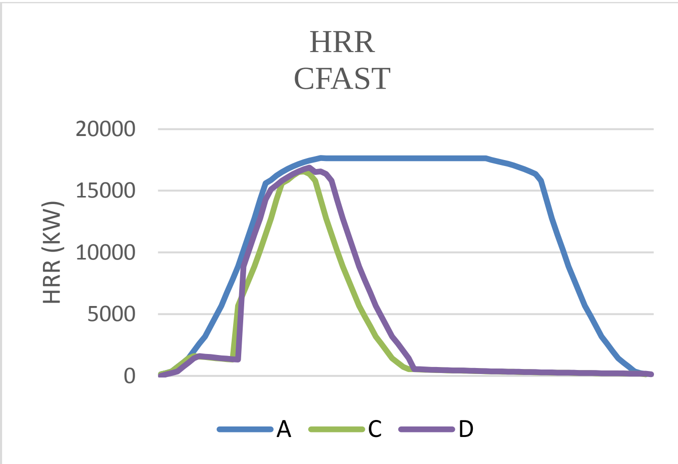

Figure 9: Comparison of HRR for different strategy

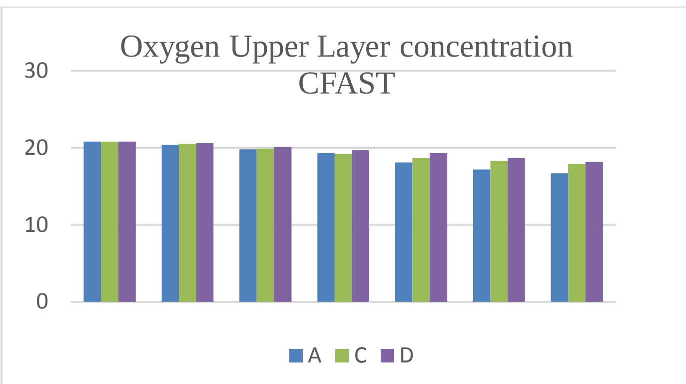

Figure10: Comparison of oxygen concentration in the upper layer for different strategy

4. CONCLUSION

In this paper, CFAST code has been applied to a warehouse compartment of books with focusing on the outputs like HRR, Upper layer temperature, Oxygen concentration and smoke transportation based on three strategies which were formed using the five basic safety measures adopted in the warehouse. One heat detector and a sprinkler system was placed in the model to dissipate the effect of fire by activating on a certain temperature of 57 degree centigrade. I was worth noting that the placement of racks which are on fire plays a vital role in fire dissipation, and positioning them near the vent escalated the fire in some simulations. The circulation of the smoke plumes in the compartment is visualized using Smokeview. CFAST provided the temperature at the upper zone and lower zone and showed a steep change between the interface, which shows that it may not provide temperature profiles at chosen locations. Variations of upper and lower temperatures, zonal interface height, temperatures of wall, ceiling and floor, activation time of smoke detector and sprinkler and their activation criteria are obtained through simulation of 900s.

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