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# Investigation on Office Fire Simulation Using FDS Software

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**ABSTRACT:** When conducting an investigation into a fire-like occurrence, one must keep in mind that determining the origin of the ignition might be the single most significant component of the investigation. These types of studies are now able to make use of both commercial and open-source tools, both of which are readily accessible. The Fire Dynamic Simulator (FDS), often known as the fire field model, is one of the most used numerical models that is utilized during fire investigations. The FDS tool was used in order to perform a digital simulation of the observations made at the fire site. Investigations were carried out on major aspects of the dynamics of the fire, such as the movement of smoke and the temperature distribution throughout the area. Therefore, early evacuation plans can be developed to save human lives by accurately assessing the direction and quantity of the smoke that is being produced by the fire. This can be done to prevent the spread of the fire. In addition, the rise in temperature may have an effect, either positive or negative, on the safety of both people and buildings. This may be the case regardless of how the temperature rises. A variety of aspects, including potential fire zones, exit routes, and doorways, were taken into account. Notable discoveries are taken into account, and conclusions are written down.

## I. INTRODUCTION

Enclosure fire experiments employ both experimental measurement and numerical analysis to examine fire dynamics and species transport. These two approaches, each with its own strengths and weaknesses, complement one another. Replicating the real fire scenario is the primary goal of a large-scale experiment, which necessitates a large workforce, a sizable budget, and a large experimental area. However, it is difficult to extend the tests or draw firm results from restricted testing since the targets of the full-scale experiment are limited, the repeatability is weak due to the unstable nature of fire, and so on. However, empirical formulas and numerical simulation results can be compared to data from full-scale fire tests to validate or improve the model. Complex large-scale fires are frequently best explored using numerical simulation analysis. Rapid progress has been made in the creation of simulation software. However, there is still potential for major improvement in numerical simulation because of an inadequate material database and incomplete physical and chemical simulation models on the material burning and pyrolysis. Therefore, the precision and utility of numerical results can be assessed using full-scale fire trials. NIST's FDS (Fire Dynamics Simulator) [1] is the numerical simulation programme most commonly used by fire departments for modelling building fires. It has also been implemented in a wide variety of contemporary research and practical applications, including the analysis of smoke and flow characteristics in a fire scenario [2, 3, 4, 5], the simulation of fires in enclosed spaces [6, 7], the reconstruction of arson fires [8, 9], and the modelling of firefighting strategies [10, 11].

FDS has also been widely utilised to model compartment fires by numerous researchers. In a 4 by 4 by 2 foot 3 cubic metre chamber, Kim and Ryou [9] employed FDS to imitate the suppression of a methyl and hexane fire with a water mist. Only 10 degrees Celsius separated the calculated temperature from the measured one. The burnout period of the fire could not be correctly predicted because there was no fire extinguishing model. ISO 9705 room tests and FDS simulations were performed by Zou and Chow [7]. In order to determine flashover time, researchers altered the ventilation conditions and the size of the pool fires used in the experiments. The results confirmed that the temperature or heat radiation measured experimentally agrees with those predicted by the FDS simulation. Close to the roof, the simulated temperature was within 10% of the experimental value. The estimation of flashover time is aided by this.

The FDS demonstrated high parameter dependence for the simulation of a full-scale experiment outcome [10, 11]. Fire development sensitivity (FDS) modelling was investigated by Jahn et al. [10], who looked at how different inputs (fire size and position, convection, radiation, and combustion factors) affected model results. It has been found that the location, heat release rate, fire area, flame radiative fraction, and thermal and ignition properties of materials play crucial roles in fire growth simulations. The modelling forecast of the Dalmarnock Fire One Test was the subject of a round-robin investigation by Rein et al. [11]. There is a high dispersion and significant difference between the forecasts, and between the predictions and experimental observations, as shown by the round-robin modelling findings.

Smoke propagation, local temperatures, and gas component and velocity calculations are only some of the insights gained from using FDS in fire simulations. Its reliance on modelling does, however, lead to some restrictions. As an illustration, FDS is limited to predicting the combustion of a single gaseous fuel, which can lead to inaccurate results in scenarios involving numerous fuels. Fire detection systems (FDS) have been shown to be unable to accurately predict fires in tiny compartments or vented fires following research conducted in Edinburgh [11, 12]. To model realistic enclosure fires, it is necessary to use experimental measurements from fire tests that are relevant to the phenomenon under study, as a whole.

The aim of this research is to Comprehensive literature review of office fire simulation using FDS software analysis. Examining how fire and smoke spread in commercial buildings FDS is the most popular software for preparing for and resolving real-world fire problems. The information must be entered into FDS software, which will subsequently display the final result graphically.

## II. METHODOLOGY

If you're looking into a fire that broke out in an office building, for example, you'll want to know exactly what you're looking for in terms of evidence. Collect information about the building's layout, fuel loads, ventilation, and potential fire scenarios to use in the simulation. To do this, it may be necessary to gather blueprints, data from the HVAC system, and other information specific to the office building and the fire occurrence under investigation. Create a numerical model of the office building using FDS, specifying its shape, materials, fuel loads, and other factors with the acquired data. Create the fire conditions by establishing the ignition point, the rate of fire spread, and any other relevant factors. To model the fire's behaviour over time, run the simulation in the FDS programme. Keep track of data as it comes in, including smoke patterns, temperature variations, and more. Examine the simulation outcomes, showing the flow of smoke and the temperature distribution around the workplace. Gather data such as possible smoke routes, hotspots, and areas of buildup. Apply the goal of the inquiry to the simulation results and explain the findings. The office block fire behaviour can be better understood if we can pick out patterns, trends, and crucial results. Create early evacuation plans based on simulation results, considering smoke patterns, potential fire zones, and escape routes. Evacuation plans should be tested to see how well they perform in preventing loss of life during a simulated fire.

## III. SYSTEM IMPLEMENTATION

### 3.1. Fire dynamics Simulator

FDS, a cutting-edge computational fluid dynamics (CFD) simulator, properly represents fires in complex and dynamic situations. Modelling fire's interaction with its environment achieves this. Simulating fire and its environs achieves this goal. It was invented to mimic flames, hence its name. This drove technical progress. FDS was introduced in 2000 by the US National Institute of Standards and Technology. NIST released this edition. FDS 5.5.3 is the latest public version. FDS's initial edition was made public in 2000. FDS solves the Navier-Stokes equations for fire-induced flows at low velocities. Before anything else, smoke and heat must be removed from the fire area.

### 3.2. Heat Release Prediction and Data

Fire simulation programme FDS5 can calculate pyrolysis and burning rates. Calculations are based on material reaction kinetics. This approach can model cone calorimeter data from small-scale fire studies and get outstanding results. Due to the extensive study being done on heat release rate (HRR), large-scale HRR predictions will be possible in the future. However, simpler phenomenological explanations are being given. This research uses simple combustion features to measure the strategy.

The Thermal Efficiency Per Unit Area (HRRPUA [kW/m<sup>2</sup>]) that can be determined by the cone calorimeter and has been tested for most combustibles in our daily environment due to its ease of measurement. Measurements are possible.

The Actual Ignition temperature (EHC [MJ/kg]), which can be measured with a cone calorimeter or bomb calorimeter.

### 3.2.1 Heat Release/Unit Area

Real-world fire loads are diverse. Each component has a unique heat release rate per unit area (HRRPUA), abbreviated as  $Q$  in the following sections. Heat is symbolised by  $Q$ , temporal change by a superscript-dot, and area-specific quantity by a superscript double prime. It depends on the material it was made from and the heat applied during manufacturing.

HRRPUA is harder to solve because it depends on heat exposure, or more particularly, heat flux impinging on the material or product. As the fire progresses, the actual surface heat flux changes. Most cone calorimeter tests use 50 kW/m<sup>2</sup> heat exposure. After extensive research, this number represents typical fire exposure. This decision led to the technique using HRRPUA values that correspond to a heat exposure of 50 kW/m<sup>2</sup>. These values are acceptable.

### 3.2.2 Heat Of Combustion

Complete combustion (cH) is the thermal energy produced by burning a unit amount of combustible substance. Burning is also called this. The fire's heat comes from the exhaust temperature, commonly known as EHC or 'Hc, eff,' even though combustion efficiency is often less than unity. This is because exhaust temperature imbues the fire with burning heat. Formally, we could write it.

### 3.2.3 Density, specific heat, and thermal efficiency

Forest Products Information System lists cellulosic product densities.

solid wood, often 400–800 kg/m<sup>3</sup> (but balsa and oak are lighter and heavier).

particle and MDF boards, 600–800 kg/m<sup>3</sup>. Paper: 500–1100 kg/m<sup>3</sup>. Plywood: 400–800 kg/m<sup>3</sup>.

### 4.3 Office Workstation Fire

This approach can be seen in the presentation of the findings of a fire experiment at a firm on a workstation. This fire safety drill took place at one of the location's workstations. The experiment was performed at one of the site's workstations. The experiment requires igniting a fire in the work area. Must have. This must be done on-site. After the fire is extinguished, an investigation will determine the cause and contributing circumstances. This type of workstation has a higher fire risk due to its flammable components. Safety steps can lessen this risk. Each of these materials has a more complex geometry than those previously discussed. Because of this, simulating it using the simple approach described here will be difficult to complete.

## IV. RESULTS AND DISCUSSION

The FDS simulation would measure the temperature of the air at the ceiling of the room while it was on fire. The data may show a time-varying temperature profile or point temperatures near the ceiling. The temperature distribution in the room during the fire can be analysed using the findings of the simulation. Checking for temperature differences, hotspots, and cool spots near the ceiling may be part of this. The simulation's temperature data can be used to gauge how well preemptive measures fared. In order to maintain the safety of residents, it may be necessary to make adjustments to evacuation routes or methods if, for instance, the temperature near the ceiling suddenly rises and reaches dangerous levels.

The movement of smoke within the room, which might affect visibility and escape routes during a fire, may also be revealed by the simulation. Using the temperature readings, firefighters can figure out which way the smoke is blowing so they can put together better measures to contain the smoke and enhance evacuation routes. Increases in temperature during a fire can threaten the well-being of both humans and structures. The findings of the simulation can be used to evaluate the danger posed by the fire to the building's structure and the safety of its occupants in terms of heat. Fire prevention and protection strategies can be improved with the help of this data. The validity and limitations of the simulation results should be evaluated as part of the debate. Comparison with experimental data or actual fire events, as well as the quality of input parameters, are all important considerations.



#### 4.1 Input Parameters

The aim of the FDS simulation we are about to create is to measure the air temperature near the ceiling during a room fire.

##### Input data:

Room dimensions:	3 x 4 x 3 m
Door dimensions:	1 x 2 m
Window dimensions:	1 x 1 m
Burning object location:	middle of the room
Heat release rate:	750 kW

##### 4.1.1 Setting up The Model Domain

This domain will act as the model grid for the simulation of the office fire. For this simulation, domain has been divided into 3 x 4 x 3 m into cubes with 0.1 m side.

##### 4.1.2 Setting Up The Duration Of The FDS Simulation

The duration of the simulation will be updated as 60s and the time frame for each second will be 60.

##### 4.1.3 Modelling the Combustion

The fuel of the simulation will be propane and the heat release rate per unit of area to the surface of obstruction.

##### 4.1.4 Code for the Simulation

```
&HEAD CHID='job1', TITLE='job1' /
&MESH XB= 0, 3, 0, 4, 0, 3, IJK= 30, 40, 30 /
&TIME T_END=60. /
&DUMP NFRAMES=60 /
&VENT XB= 1, 2, 4, 4, 0, 2, SURF_ID='OPEN' / door
&VENT XB= 3, 3, 2, 3, 1, 2, SURF_ID='OPEN' / window
&REAC FUEL = 'PROPANE'
&OBST XB= 1, 2, 1.5, 2.5, 0, 0.5, COLOR='RED', SURF_ID='fire1' /
&SURF ID='fire1', HRRPUA=250 /
&DEVC ID='T air 1', XYZ=1, 2, 2.8, QUANTITY='TEMPERATURE' /
&SLCF PBY = 2, QUANTITY='TEMPERATURE'/
&TAIL /
```

#### 4.2 OUTPUT RESULTS

```
Reading FDS input file ...
Fire Dynamics Simulator
Current Date : November 22, 2022 17:27:01
Revision : FDS6.7.9-0-gec52dee42-release
Revision Date : Sun Jun 26 14:36:40 2022 -0400
Compiler :
Compilation Date : Tue 06/28/2022 11:17 PM

MPI Enabled; Number of MPI Processes: 1
OpenMP Enabled; Number of OpenMP Threads: 4

MPI version: 3.1
MPI library version: Intel(R) MPI Library 2021.6 for Windows* OS

Job TITLE : job1
Job ID string : job1

Time Step: 1, Simulation Time: 0.09 s
Time Step: 2, Simulation Time: 0.18 s
Time Step: 3, Simulation Time: 0.27 s
Time Step: 4, Simulation Time: 0.37 s
Time Step: 5, Simulation Time: 0.46 s
Time Step: 6, Simulation Time: 0.55 s
Time Step: 7, Simulation Time: 0.61 s
Time Step: 8, Simulation Time: 0.66 s
Time Step: 9, Simulation Time: 0.71 s
```

Fig 4.1 Output



```
Time Step: 2400, Simulation Time: 30.68 s
Time Step: 2500, Simulation Time: 31.95 s
Time Step: 2600, Simulation Time: 33.26 s
Time Step: 2700, Simulation Time: 34.63 s
Time Step: 2800, Simulation Time: 36.05 s
Time Step: 2900, Simulation Time: 37.41 s
Time Step: 3000, Simulation Time: 38.76 s
Time Step: 3100, Simulation Time: 40.12 s
Time Step: 3200, Simulation Time: 41.45 s
Time Step: 3300, Simulation Time: 42.91 s
Time Step: 3400, Simulation Time: 44.29 s
Time Step: 3500, Simulation Time: 45.70 s
Time Step: 3600, Simulation Time: 47.08 s
Time Step: 3700, Simulation Time: 48.49 s
Time Step: 3800, Simulation Time: 49.88 s
Time Step: 3900, Simulation Time: 51.24 s
Time Step: 4000, Simulation Time: 52.64 s
Time Step: 4100, Simulation Time: 54.01 s
Time Step: 4200, Simulation Time: 55.40 s
Time Step: 4300, Simulation Time: 56.83 s
Time Step: 4400, Simulation Time: 58.15 s
Time Step: 4500, Simulation Time: 59.55 s
Time Step: 4530, Simulation Time: 60.00 s

STOP: FDS completed successfully (CHID: job1)
C:\Users\user\Desktop\Job 1>
```

Fig 4.2 Simulation Completed

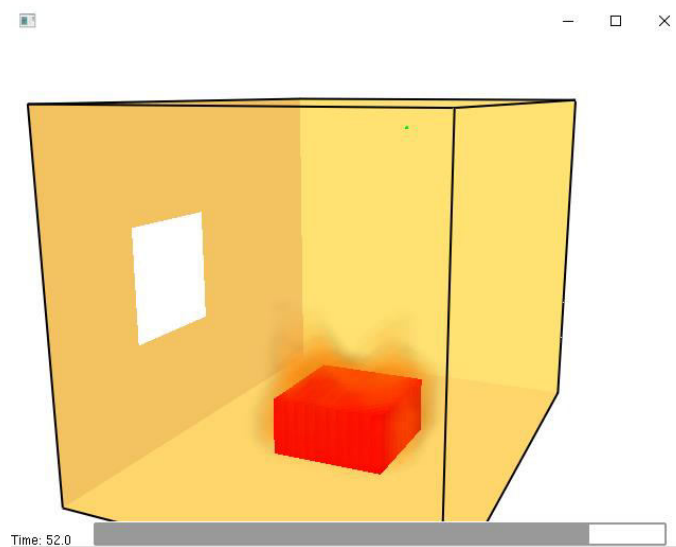


Fig 5.3 3D View of Smoke

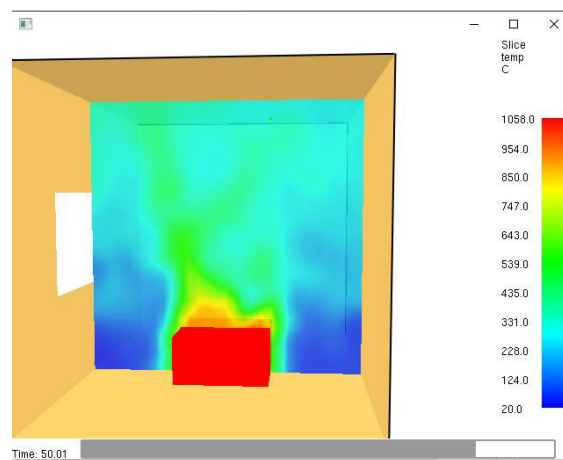


Fig 4.4 Temperature Slice

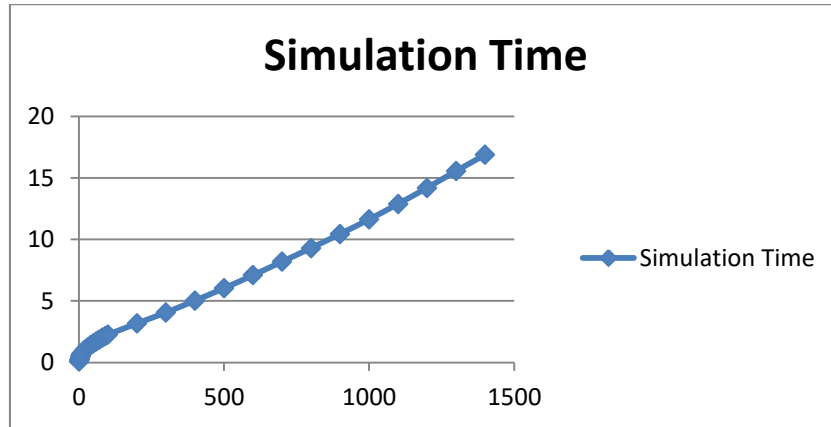


Fig 4.5 Simulation Time

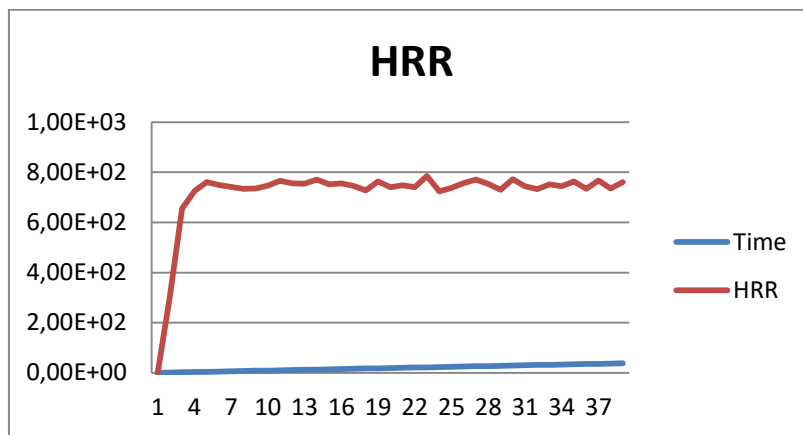


Fig 4.6 HRR

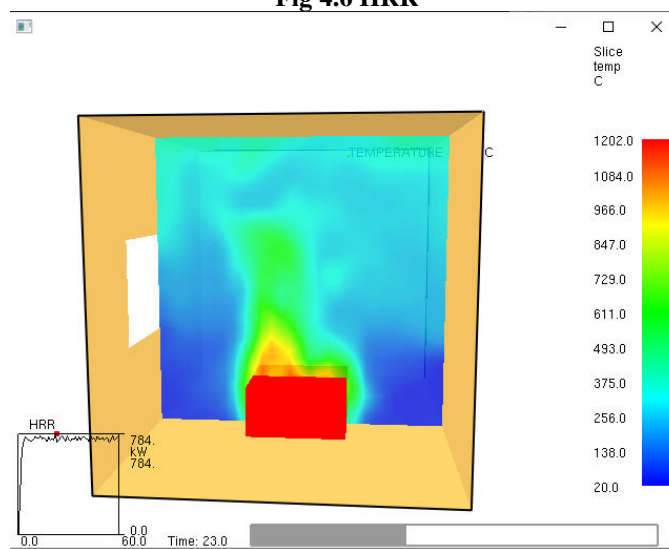


Fig 4.7 Methane Fuelled

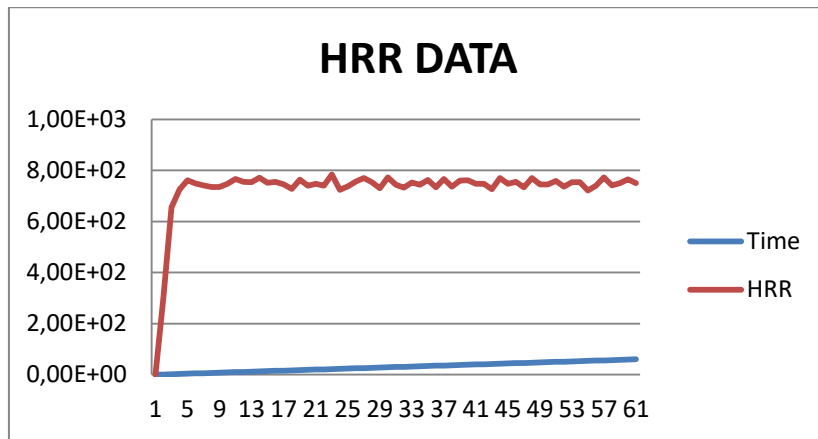


Fig 4.8 HRR Data

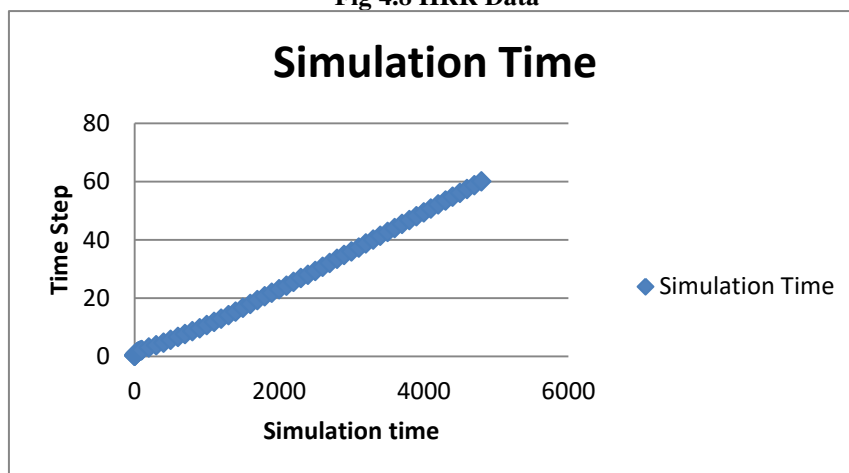


Fig 4.9 Simulation Time

### V. CONCLUSION

For the purpose of investigating the development and spread of fire, experiments were carried out in an actual model room that had both moving and permanent fire loads. After that, numerical simulations were run with parameter adaption using the FDS programme to forecast the fire characteristics, and the results of these simulations were verified with the findings of the experiments. During the time that the fire was growing, there was a correlation between the experimental findings and the numerical simulations. This was true for the flashover time, the maximum heat release, and the amount of time needed to reach the combustion temperature peak. The gap between the observed findings of the experiment and those predicted by the model widened when considering the case of continuous burning. The qualities of the material are a factor that has a significant impact on the simulation results. We compared the effects of the density of the fuel and the amount of ash it contained on the progression and spread of flames using methane and propane as our test substances. It would seem that methane produces more heat than propane does, and the transfer rate is both excessively high and potentially dangerous.

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