HISYAM BIN MOHAMED

B.TECH (HONS) MECHANICAL ENGINEERING

SEPTEMBER 2013

COMPUTATIONAL FLUID DYNAMIC MODELLING OF FIRE INCIDENT

HISYAM BIN MOHAMED

MECHANICAL ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS
SPETEMBER 2013

COMPUTATIONAL FLUID DYNAMICS MODELLING OF FIRE INCIDENT

by

Hisyam Bin Mohamed

Bachelor of Engineering (Hons)
(Mechanical Engineering)

SEPT 2013

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

\

CERTIFICATION OF APPROVAL

COMPUTATIONAL FLUID DYNAMICS MODELLING OF FIRE INCIDENT

by

Hisyam Bin Mohamed

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

____

(Dr. Mohammad Shakir Nasif)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
SEPT 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

HISYAM BIN MOHAMED

ABSTRACT

This proposal outlines the background of the project "Computational Fluid Dynamic Modeling of Fire incident". Fire incident is one of the incidents causing casualties, property damage to some circumstances it will also causing death. Fire incident may due to some explosion of the electrical application, short circuit or due to the unintentionally burning activity. Nonetheless, limited research has been done on fire incident in order to investigate the cause of fire, the spread of fire with respect to the material surrounding during the incident and this will focus on one case study of the Terwindle Rest House Fire incident. Based on the investigation report (Byrne1994), this fire resulted in seven fatalities and extensive fire damage to the building. It is found that the primary cause of the death was carbon monoxide poising from smoke inhalation. The fire believed started by the unintentionally placing the paper on the mounted electric heater which located behind one of the couches inside the lounge. The rate of fire growth become faster once the couch start to ignite as all the couches is made up of polyurethane foam padding. Nowadays, lots of fire simulation software has been developed in order to investigate real fire incident situation and however, the validation of the simulation result is still the most important issue whether this fire simulation can be used as the investigation tool of the real fire incident simulation.

In this Final Year Project ,the Terwindle Rest Home Fire Incident is modelled and simulated using Computational Fluid Dynamics (CFD) software FDS (Fire Dynamic Simulator). The results of the simulation were validated against the approximate time scale of the growth of fire incident as it was found from the fire investigation report. Based on the validation process, it is found that Fire Dynamic Simulator (FDS) can provide accurate simulation to the fire which can be used to perform fire investigation provided that the correct heat release rate of the fire used in the model. This will explains the objectives of this project which is to validate the accuracy the simulation related to real fire incident and to validate the CFD fire model as the investigation tool for fire incident.

ACKNOWLEDGEMENT

First and foremost, the author would like to express his highest gratitude to her supervisor, Dr. Mohammad Shakir Nasif, for all the motivation, knowledge and valuable advices that he has given. The guidance and supervision from him have granted her many opportunities to explore, learn and experience throughout the project.

This project will not be successful without the technical helps from the Mr. Ali, Master student who had provided the author constructive advices and valuable assistances in accomplishing the project. Your kindness and hospitality provide the author a comfortable and conducive working environment.

Finally, the author would like to extend her appreciation to Universiti Teknologi PETRONAS for providing the facilities and many learning opportunities, and to her family and friends who constantly support her throughout the project.

TABLE OF CONTENTS

LIST OF FIGURES

Nomenclature:

$\dot{q}$ = radiated heat flux (kW / m^2)

X = factor that varies between 0.15 for low sooting fuel to 0.6 for high sooting fuel. In this fire X is assumed to be 0.5.

$\dot{Q}$ = heat released rate from couch A (kW)

R_o = distance of couches (m)

t_{ig} = time taken of couch to start ignite (s)

α = 0.1kW/s^2 (Karlsson and Quintiere 2000)

F = fraction of an incapacitation dose of all narcotic gases

F_{ICO} = fraction of an incapacitating dose of CO

F_{ICN} = fraction of an incapacitating dose of HCN

VCO_2 = multiplication factor CO_2 -induced hyperventilation

F_{IO} = fraction of an incapacitating dose of low oxygen hypoxia

CHAPTER 1

INTRODUCTION

1.1 Project background

Fire is the human enemy that is destructive in nature and cause sorrow and anxiety in home when it consumes lives, (Ibrahim, 2012). Fire incident is one of major incident that contribute in increasing percentage of civilians death. Fire death can be categories into three part which are (a) smoke inhalation and burn only, (b) smoke inhalation only and (c) burn only. In 2004 – 2008, home structure fires has reported to U.S. municipal fire department that 45 % of civilians death resulting from both burn and smoke inhalation, while 40 % of death were due to smoke inhalation only and the rest 5 % were due to burn only, (Hall. Jr and John 2011, Gritch.T and Eason 2009, Ho 2010). For non- fatal home fire civilian injuries, 41 % were due to smoke inhalation only, (klote and Milke,2002) , while 25 % were due to burn only, and 13 % were due to the smoke inhalation and burn only, (Hall. Jr and John, 2011). Previous studies showed that more than 50 % of deaths occurred in fire accidents because of inhalation of smoke (Klote and Milke, 2002). Smoke created during the fire was contained specific toxic gases such as carbon monoxide gas.

Fire releases smoke which has toxic effects because combustion product contains some irritant chemicals and asphyxiant gases like CO, CO2 and hydrogen cyanide (HCN), (Hasnain. et al 2014). The Terwindle Rest Home Fire Incident has been choosing as the case study to understand clearly about the fire incident. Fire is form of heat and fluid which can be spread into two ways which are 80 % is through radiation and another remaining 20 % is through convection, (Heskestad, 2012). The amount of heat transfer is measure in heat flux. Fire can occur if only if there are 3 element of fire such as source of fuel, oxygen or gas and source of heat exist. The phenomenon of fire spreading is mostly due to the insufficient of oxygen gas to maintain the combustion process

The aim project is to remodel and simulate real fire incident of the Terwindle Rest Home by using computational fluid dynamic techniques. This method will use the Fire Dynamic Simulator (FDS) to reconstruct the building interior design, temperature, smoke layer height, carbon monoxide density, and fire hazard factor over the time variation and personal evacuation time. By applying the computational fluid dynamic techniques onto the fire incident, it will help in understanding the fire phenomena consisting of combustion, radiation, convection, radiation, fluid dynamic and main factor that contributing to death in the fire incident.

1.2 Problem statement

Building safety precaution is very important in determining whether the building is save enough to be use in the future. This safety precaution will also include the prevention related to fire incident. Most building nowadays has equip with the fire detector and smoke extraction as a prevention and evacuation process toward fire incident. However, these device cannot be simply install without taking the potential location of fire starting point as well as the fire evacuation of the building. The suitable location for the device installation can either identify through manual experiment or using simulation software as the investigation tool. Manual experiment is very costly and actually take more time to be analyzed. Thus, one of the way to reduce to cost and less the investigation time is by using a simulation software.

Nowadays, there are lots of simulation software can be used to simulate certain problem in order to solve them without do any experiment in the lab. Fire dynamics is one of the famous software that is used to modeling, simulating the problem related to fire incident. This software is used to investigate the characteristic and behavior of the fire incident by simulating the exact fire incident using the computer. However, some of the simulation of the fire incident problem, the result of the simulation is not exactly the same which has been showed in the fire incident report. As a result, this simulation cannot be used as a tool to investigate the fire incident problem. Thus, some validations need to be done in order to validate the result of the simulation of the fire incident problem to be used as the data for investigation of real fire incident problem.

1.3 Objective

The main objectives of the research are:

1. To validate the accuracy of CFD fire model simulation against the fire incident report
2. To utilize the CFD fire model as investigation tool of fire incident
3. To identify safety issues with regard to fire incident.

1.4 Scope of project

The scope of project for this f 10 year project research to research about factor of fire incident including the characteristic of fire, the fire cause and fire phenomena like radiation heat transfer, convection heat transfer, turbulence, fluid dynamic and flammable tendency of certain material with respect to fire incident. Moreover research is focus only of the case study of the Terwindle Rest Home Fire Incident. During the period, the critical analysis will be provided and project modeling were designed by using computational fluid dynamics of fire dynamic simulator (FDS) to validate the fire simulation result and compare based on the real fire incident of the Terwindle Rest Home.

1.5 Feasibility of the project

Within 5 month of the project completion, the expectation is the critical analysis of the fire incident case happened at the Terwindle Rest Home and modeling of the layout of the fire scene should be done in order to simulate the fire incident. This focus is on the behavior of the fire incident such as the spreading of the fire, the starting point of the fire and the behavior of the fire smoke accumulation. This project required to use the computational fluid dynamic so that it will finish within the time frame with some expected modeling result using computational fluid dynamic method.

1.6 Relevancy of project

During the fire incident, there are some parameter which might affected the behavior of the fire incident such as the design of the building and the flammable tendency of material which might direct or indirectly lead to encourage the spreading of the fire. Using the below information in order to determine the condition of the fire incident

- Characteristic of the fire
- Original design or layout of the building
- The history of the fire incident
- Factor lead to fire starting point

CHAPTER 2

LITERATURE REVIEW

2.1 Terwindle Rest Home Fire Incident Case Studies

Terwindle rest home fire incident case is happened in Aukland , New Zealand.. Terwindle rest home fire incident was happened in 10 July 1989 and this fire has resulted in seven fatalities and extensive fire damage to the building, (Nasif. et al, 2010). The primary cause of the death was due to the inhalation of smoke that contain carbon monoxide. The fire incident has taken place at rest home which is one of three residential buildings on the site, all part of the terwindle complex. The building in which involved in fire occurred was licensed for use as a rest home for the numbers and capabilities of the residents accommodated, (Byrne, 1994)

The Terwindle Rest Home was a building which converted from a large residence by alterations and additions, the most recent being completed in 1988. The rest home was initialy a single storey building on a gently sloping site with the good vehicle access right up to the building, (Byrne, 1994). During the fire incident, most of the occupant were older people with have psychiatric disabilities and it was believed that all of them were receiving medication and had taken prescribed sleeping medication in the evening and were in bed at 9pm. This medication most probably was contributed factor in delaying their waking up and affected their ability to escape from the building (NZ Fire Service-NZFS).

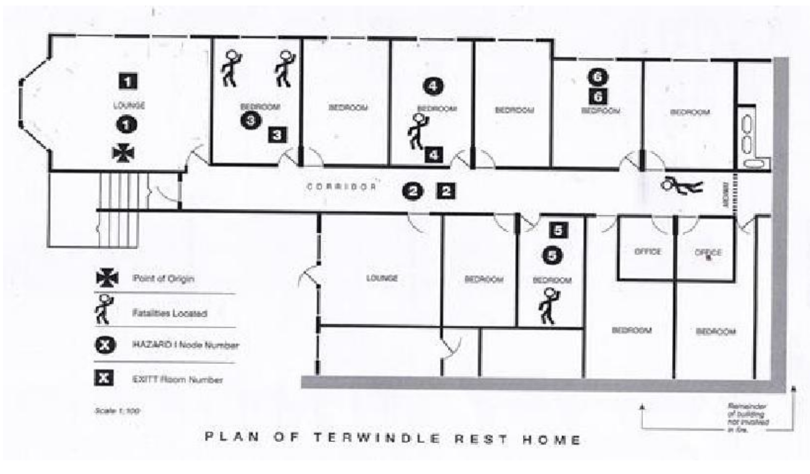


Fig 2.1 Design layout of the Terwindle Rest Home (Byrne, 1994)

2.2 Fire scene

New Zealand Fire Statistic (NZFS) has concluded that the starting point of the fire incident was a wall mounted heater in the lounge (Byrne, 1994). The cause of fire was due to liberate ignition is either by placing the paper in the heater or lighting combustible material close to the heater which suspected done by one of the residents in the Terwindle Rest Home. The fire incident was not discovered until the lounge is well involved with the fire. The fire has spreader faster and only discovered by two staff on duty on that day heard the noise due to the window breaking. it is expected that the fire and smoke have spread through the corridor via the lounge door which was left open, (Nasif and Al-Waked, 2013)Below is the layout of the lounge where the starting point of the fir incident

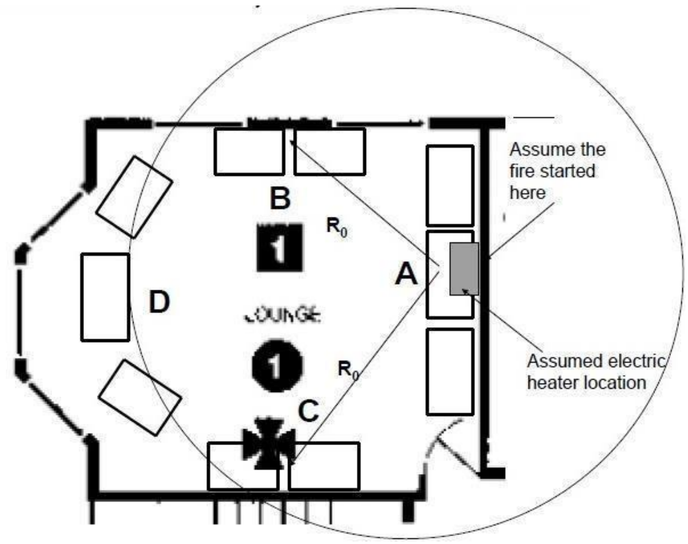


Fig 2.2 Assumed furniture layout at the lounge (Nasif et al. 2010)

Upholsters couch A was the nearest couch to the wall mounted heater. The couch was made of polyurethane foam padding that has flammable tendency to burn. The couch A will catch the fire from the wall mounted heater and start to burn. The heat from the fire was then transferred to the couch B and C through radiation.. The couch that made of polyurethane foam padding required 20 kW/ m^2 amount of heat flux in order to start ignite, (Chen, 2001). Couch D is the last couch caught on fire once the couch B and C well involved with fire. This is due to the radiation heat flux transferred from couch A was insufficient to cause the couch D to ignite by itself.

Actual Time	Elapsed Time (min)	Event
9:15	0	Staff member did rounds and noticed nothing untoward.
9:45	30	Fire discovered by staff member, manual fire alarm operated, staff started to rescue occupants.
9:45-10:00	30-45	Estimated time of flashover in lounge.
10:00-10:15	45-60	Estimated time when the six fatalities occurred.
10:15	60	First 111 call received by New Zealand Fire Service control room and first appliances despatched.
10:19	64	First fire appliances arrived at incident.
10:20	65	"Second Alarm" message transmitted for further assistance required.
10:37 required.	82	"Third Alarm" message transmitted for further assistance
10:52	97	"Terwindle Rest Home well involved in fire, multiple rescues" message transmitted.
10:53	98	"All Persons Accounted For" message transmitted.
11:34	139	Message transmitted indicating five fataities and thirteen people removed to hospital by ambulance.
11:51	156	"Stop" message transmitted, fire fully under control, no further assistance required.

Fig 2.3 (Byrne 1994): Time Scale approximation of Terwindle Fire Incident

Based table 1 above, it can be seen that the New Zealand fire service received the first call at 10.15 p.m. which approximately 30minutes after the fire is been discovered by the staff member at 9.45 p.m. At this stage, the building was heavily involved in a fire as the flashover period already occurred. The late of received first call by the New Zealand Fire service was due to the fact the Rest Home staff attempted to phone 111 but the phone was dead and sent someone to call from neighboring building. The fire brigade arrived at 10.18 which is 5 minutes from receiving the call. During that time, the fire was developed rapidly and spread to bed rooms adjacent, to the ceiling space and corridor along the building.

2.3 Fire dynamic simulator modeling.

Fire dynamic simulator is a computational fluid dynamic (CFD) model of fire- driven fluid flow and it 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 fires, (McGrattan et al, 2010). The model aims to model the real fire through using Fire Dynamic Simulator software and validate the results against the approximate time scale of the progress of the fire as it was found from the witness, NZFS call centre records, and the medical reports of the deceased

(Figure 2.3). In this study, the design fire used in the modelling process is based on heat release rate measured from burning a couch. Smoke view is a companion program to FDS to produce images and animation of the result from the fire simulation. Smoke view is able to visualize fire and smoke in a fairly realistic way.

2.4 Design fire modeling

Heat and mass transfer occur at the interface of the couch surface and the surrounding air, mainly by convection and radiation. A model has been developed to study the heat and mass transfer process of the heat flux generated by the couch.. The main objective of this model is to show the fire incident generated in a confined space as the higher heat flux radiated throughout the space. When reconstructing the fire scene using the computer program, calculating the heat release rate (HRR) generated at the fire originating location is a very important process, (Chi et al 2011 and Shen et al.2008). The radiated heat flux from couch A is calculated using Modak's method (Karlsson and Quintiere 2000) as follow

$$\dot{q} = \frac{X\dot{Q}}{4\pi R_o^2} \qquad (2.1)$$

The material of couch A,B, C and D is mainly made of polyurethane foam padding. Radiated heat flux required to cause polyurethane foam to ignite is 20kW/m^2 (Chen 2001). Time required for the fire to grow to the peak is calculated using t^2 method where the peak, Q is based on the heat released rate during the flashover period.

$$Q = \alpha t^2 \qquad (2.2)$$

Modak's method assume that the fire generated by the couch A is in cylinder shape. The radiated heat flux from the couch A will cause the couch B and C burn in certain interval of time and it is calculated based on ignition time taken by the couch B and C to start ignite (Nasif et al. 2010).

$$t_{ig} \frac{338}{\dot{q} - 7.8} \qquad (2.3)$$

CHAPTER 3: METHODOLOGY

Gantt Chart

Project Time Line for FYP 1

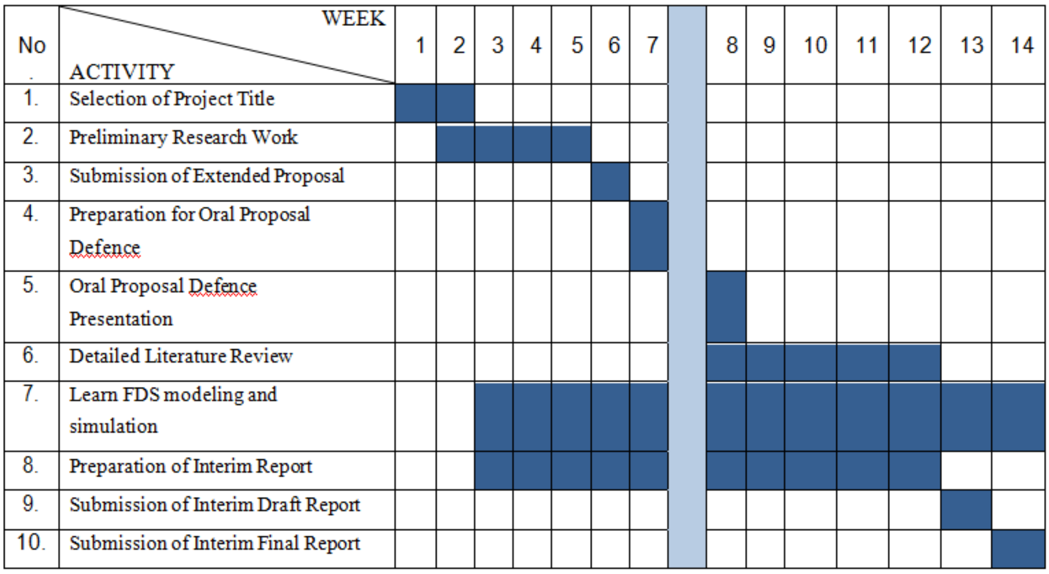


Figure 3.1 FYP1 Project timeline and schedule

Project Time Line for FYP 2

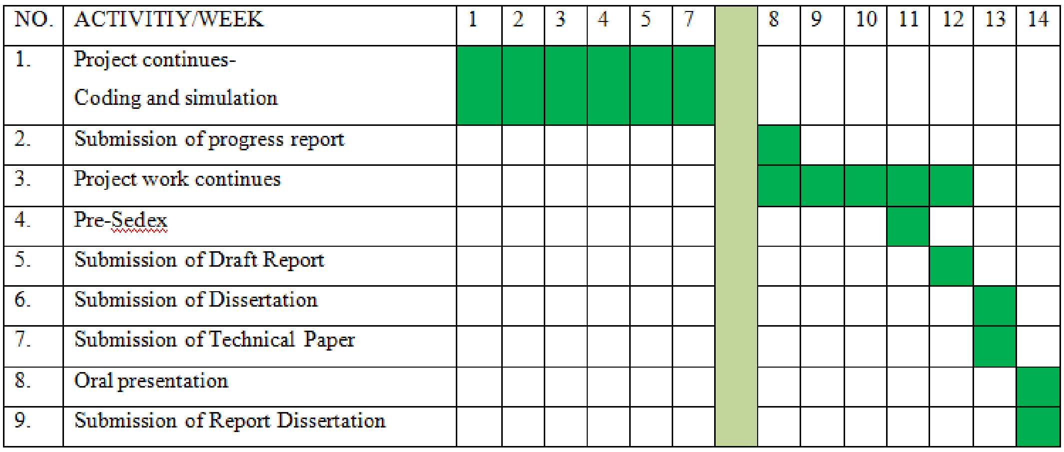


Figure 3.2 FYP2 Project timeline and schedule

Procedure Identification

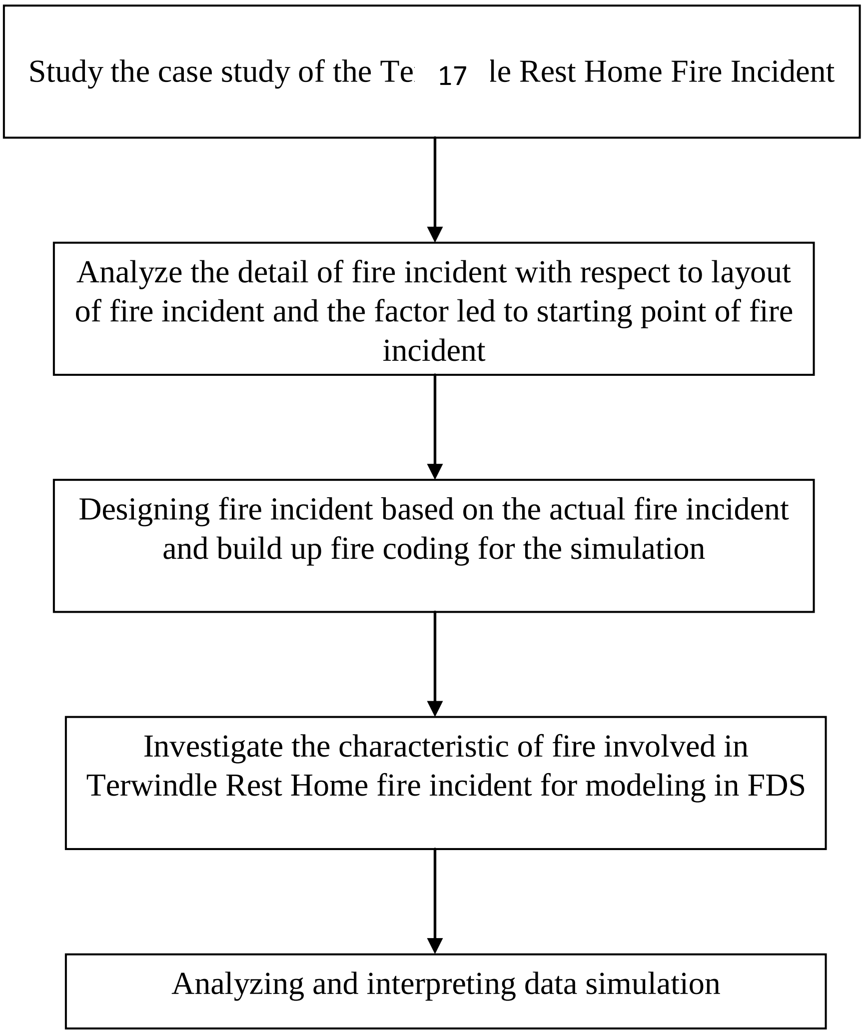


Fig 3.3 Process flows chat

The procedure involved in modeling the fire incident case study of the Terwindle Rest Home are basically based on the flow chart of the below figure. The procedures are identified to ensure the project accomplishment within time frame provided.

Figure 3.0 shows the process flow for this project. Firstly, it focused more on understanding about the fire incident happened at the Terwindle Rest Home. During first half of this Final Year Project 1 (FYP1), lots of research needs to be done regarding fire incident, the factors involved in the incident as well as the important criteria related to the fire incident. There are some important issues need to be considered before this modeling can be developed such as the design layout of the Terwindle Rest Home. Consequently this project will focus on the starting point in which fire incident started to happen and how the fire is spreading throughout the building. The purpose of this task is to develop a better understanding about fire incident in order to design in the next task. There are some important issues need to be consider before modeling the fire incident such as the evacuation or emergency exit in the building and the existence of the smoke extraction.

The last step is verifying the result data from the studies by using Computational Fluid Dynamics (CFD) method of fire dynamic simulator and analyses as well as compares the data simulation with the fire incident report for the validation process. In CFD, examination of fire and accumulation of the smoke is being extensively studied.

3.1 Design fire modeling

When reconstructing the fire scene using the computer program, calculating the heat release rate (HRR) generated at the fire originating location is a very important process, (Chi et al. 2011 and Shen et al. 2008). A design fire of the terwindle rest home need to be model first and this modeling should based on certain parameter such as the arrangement of material, the characteristic of material and the building specification such as air ventilation inside the first starting point of the fire incident.

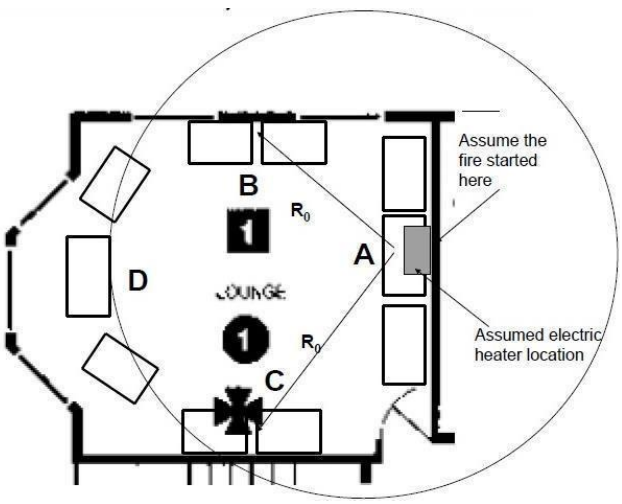


Fig 3.4 Assumed furniture layout at the lounge (Nasif et al. 2010)

From Figure 3.1, it is assumed that the fire is starting at the three couches (A) that located near the electric heater. The heat released rate of the couches A obtained from couch burning test that was performed at the University of Canterbury Furniture Calorimetry lab (Nasif et al. 2010). Figure 3.2 show the heat release rate of one couch of same material.

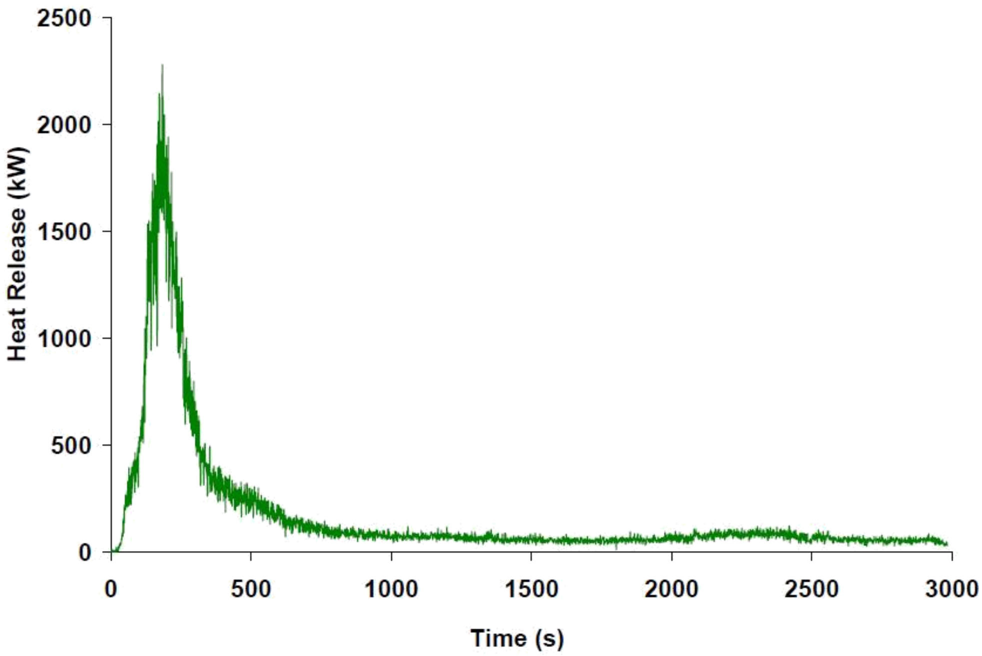


Fig 3.5 couch burning heat release rate (Nasif et al 2010)

The heat release rate obtained from the experimental is used to calculate the radiated heat flux from couch A. The heat flux generated by couch A is radiated to couches B and C as shown in figure 4. The heat flux that is radiated form couches A is calculated using the Modak's method (Karlsson and Quintiere 2000) as follow

$$\dot{q} = \frac{X\dot{Q}}{4\pi R_0^2} \tag{3.1}$$

the couches involved in the fire incident is made up of polyurethane foam padding. The heat flux required to cause polyurethane foam to ignite is 20kW/m2 (Chen 2001). The time taken for Couches B and C to start its ignition which caused by the radiated heat flux is calculated using

$$t_{ig} = \frac{338}{\dot{q} - 7.8} = 28\, seconds \tag{3.2}$$

Based on the time taken calculation, the couches B and C will start to ignite 28 seconds after the heat flux radiated is achieved 20 kW / m^2. This couches D will also start to ignite 28 second later after the heat flux radiated by Couches B and C achieved 20 kW/ m^2.

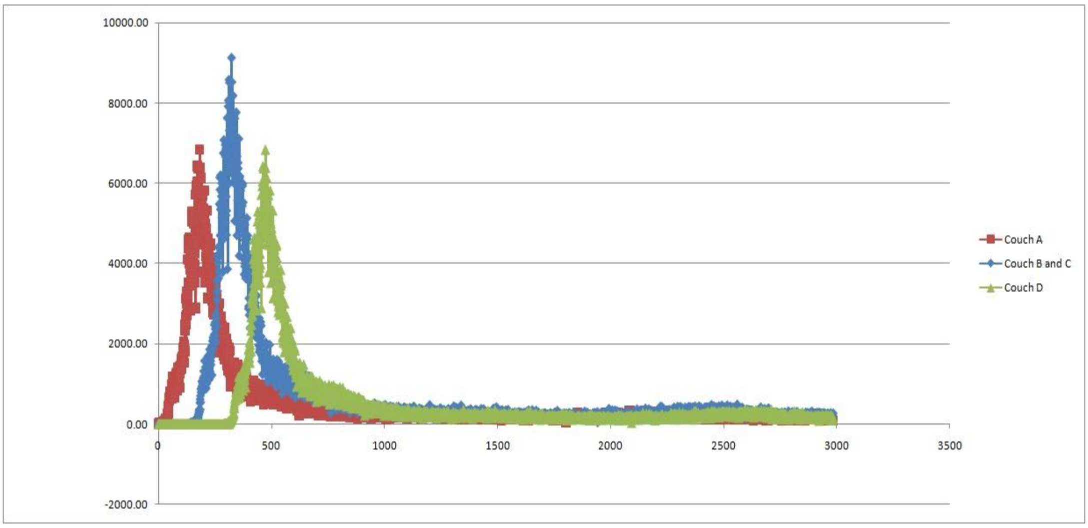


Fig 3.6 Heat release rate of couches in lounge room

Figure 3.3 shows the heat release rate of couches A,B, C and D inside the lounge room. The design fire is completed once the heat release rate of the couches is been determined. The time taken of flash over is calculated using the formula:

$$Q = \alpha t^2 \tag{3.3}$$

Once the design fire modeling is done, the data then will be used as the input file in the coding of the fire dynamic simulator for the simulation process. The simulation result then will be compare with the fire incident report for the validation process to ensure and clarify the exact incident happened at the specific time such as the flashover period.

3.2 Coding Finalization.

This section will explain on how the fire incident coding is built based on the fire incident report. This coding will emphasize on the design layout, the time taken of the fire incident as well as the device to measure the smoke layer, the fraction effective dose, the level of oxygen in the building and also the temperature inside the building.

```
&HEAD CHID = 'Rest Home', TITLE = 'Rest Home Fire Incident'/
&MESH IJK=300,48,24, XB=0.0,27.0,0.0,16.0,0.0,4.0/
&TIME TWFIN=1020.0/
&MISC SURF_DEFAULT= 'WALL'
INITIAL_UNMIXED_FRACTION =0. /
&REAC FUEL          = 'POLYURETHANE'
      FYI           = 'C_6.3 H_7.1 N O_2.1'
      SOOT_YIELD = 0.10
      N             = 1.0
      C             = 6.3
      H             = 7.1
      O             = 2.1  /

&SURF ID='POLYURETHANE',HRRPUA=533.,RAMP_Q='FAST'/Sofa

&RAMP ID='FAST', T=0.0, F=0.0/
&RAMP ID='FAST', T=30.0, F=0.02/
&RAMP ID='FAST', T=120.0, F=0.034/
&RAMP ID='FAST', T=180.0, F=0.076/
&RAMP ID='FAST', T=240.0, F=0.135/
&RAMP ID='FAST', T=300.0, F=0.212/
&RAMP ID='FAST', T=323.0, F=1.0/
&RAMP ID='FAST', T=390.0, F=1.0/
&RAMP ID='FAST', T=450.0, F=1.0/
&RAMP ID='FAST', T=480.0, F=1.0/
&RAMP ID='FAST', T=487.0, F=1.0/
&RAMP ID='FAST', T=540.0, F=1.0/
&RAMP ID='FAST', T=600.0, F=1.0/
&RAMP ID='FAST', T=660.0, F=1.0/
&RAMP ID='FAST', T=790.0, F=1.0/
&RAMP ID='FAST', T=920.0, F=1.0/
&RAMP ID='FAST', T=1020.0, F=1.0/
```

3.3 Fire simulation

This section will be more focus on the simulation using the fire dynamic simulation. Once the input file which represent the fire incident finish, it will be use as the input file for the FDS to run a fire simulation. This input file will be open using the Command Prompt, and the fire dynamic simulator software will be read the overall coding before it start the simulation.

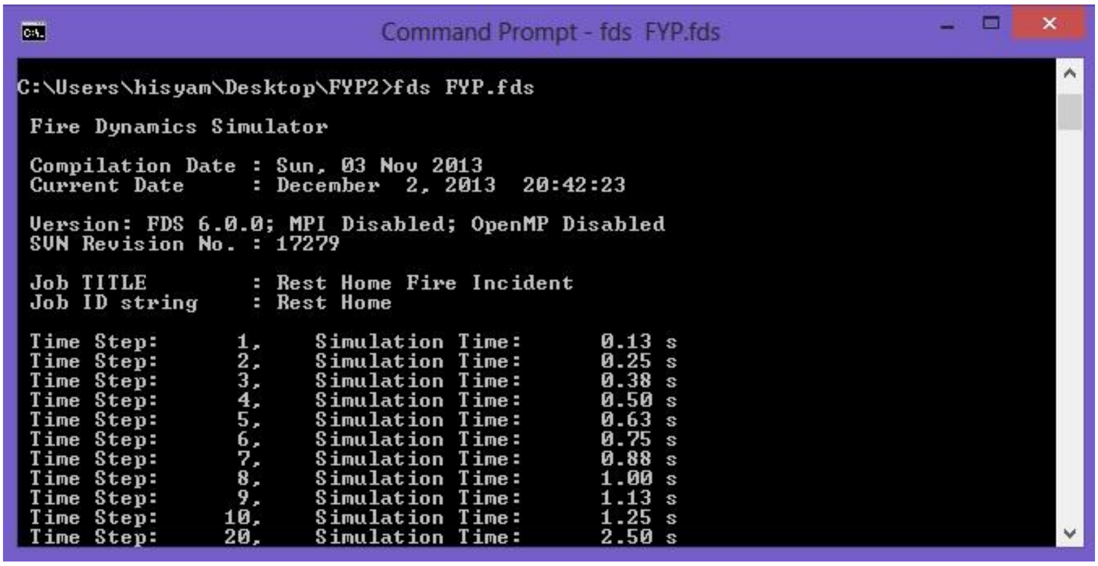


Fig 3.7 Coding initialization of fire incident using command prompt

CHAPTER 4: RESULT AND DISCUSSION

.
Data collection and analysis is done in this section. Multiple or theory and formula are being applied and the discussion part will cover the simulation result and compare it with the fire incident report for the validation process.

4.1 Data Analysis

a) Design fire calculation

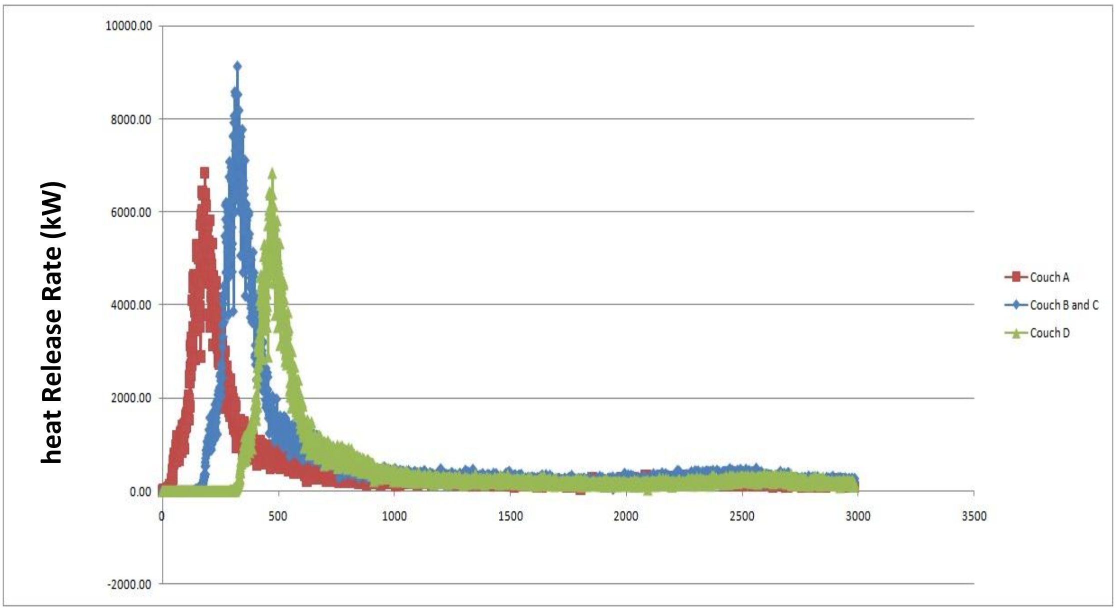


Fig 4.1 Heat Release Rate of Couches A, B, C and D

Figure 4.1 showed the graph of heat release rate by all couches. Calculation for graph of couch B and C is calculated based on the heat release rate by couch A and the time for couch B and C to start their ignition time is based on the heat flux radiated from couch A. The heat flux required to cause polyurethane foam to ignite is 20kW/m2 (Chen 2001)and it will start its ignition 28 seconds based on the calculation.

$$t_{ig} = \frac{338}{20 - 7.8} = 28 \text{ seconds} \tag{4.1}$$

The couch B and C started to ignite at time of 140 seconds, 28 seconds after the heat flux radiated from the couch A is achieved 20 kW/m^2 whereas the couch D started to ignite at time of 296 seconds after the heat flux radiated by the couch B and C achieved 20 kW/m^2.

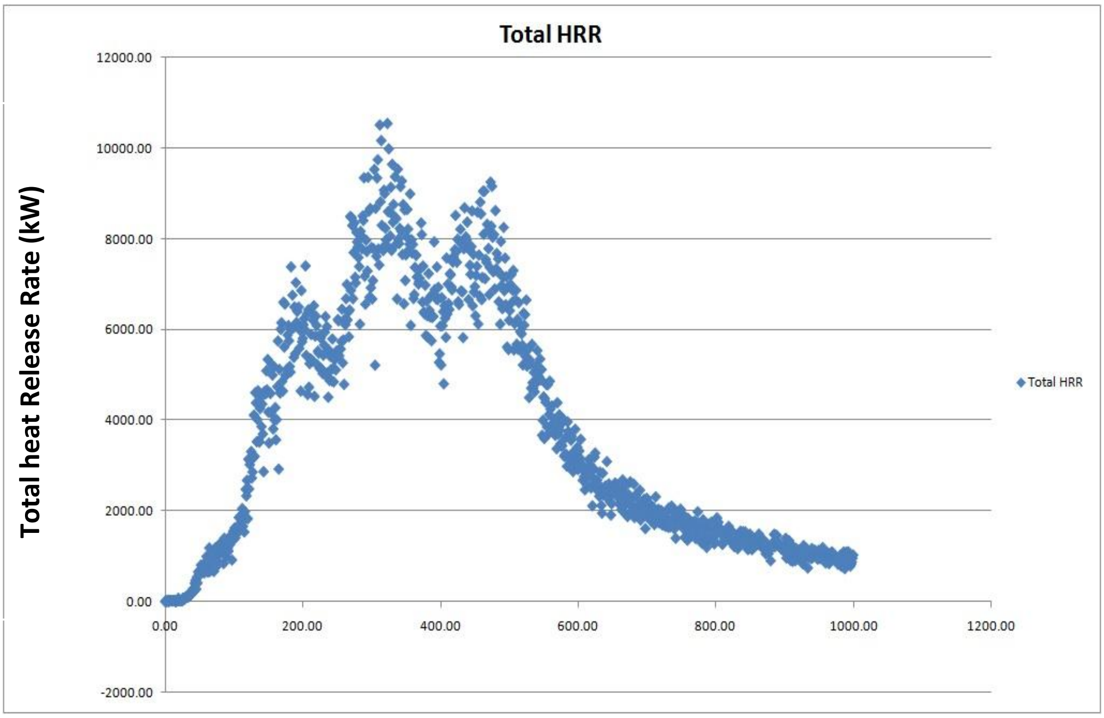


Fig 4.2 Total heat release rate

Figure 4.2 above showed the graph of total heat that has been generated or release during the fire incident. Based on the graph, the $Q_{critical}$ (heat release rate) is at 7402 kW at the time of 204 seconds whereas Q_{peak} (heat release rate at which flashover period starting is at 10541 kW at the time of 323 seconds.

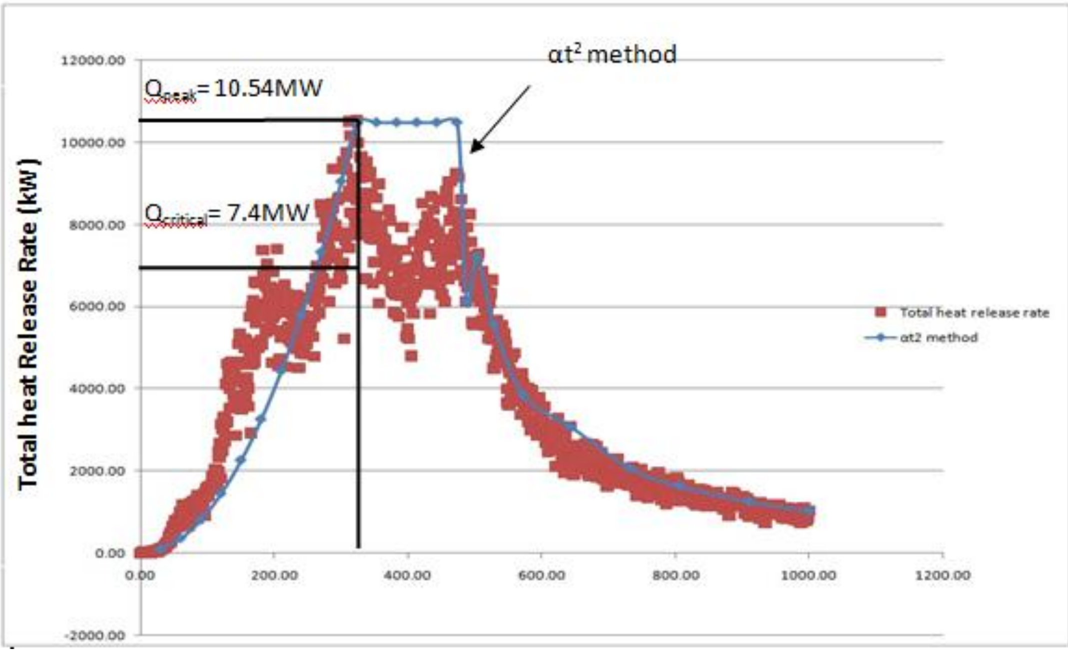


Fig 4.3 αt^2 method in total heat release rate

Figure 4.3 showed the graph represent an alternative formulation that gives the identical result which can be used to describe the heat release rate by couches. This method is indicate to the fire starting point until it reach at peak level in which fire is at flashover period. this alternative ways is calculate based on the formula below:

$$Q = \alpha t^2 \tag{4.2}$$

where, Q = Total heat release rate, t = time taken of the fire incident and α = fire intensity coefficient,(kW/s^2) = 0.1 kW/s^2 ((Karlsson and Quintiere 2000)

Data collection of the αt^2 method

t	Q using αt2 method
30	90.45
60	361.80
90	814.05
120	1447.20
150	2261.25
180	3256.20
210	4432.05
240	5788.80
270	7326.45
300	9045.00
323	10485.06
353	10485.06
383	10485.06
413	10485.06
443	10485.06
473	10485.06
487	6116.37
503	7205.85
528	5565.23
572	3848.18
642	3086.86
732	2065.21
806	1628.48
910	1255.86
1000	1029.55

Flashover period at time 323 s, and Q = 10485.06 kW based on the αt^2 method

4.2 Simulation Analysis

4.2.1 Carbon monoxide analysis

Fig 4.4 Level of CO inside the rest home

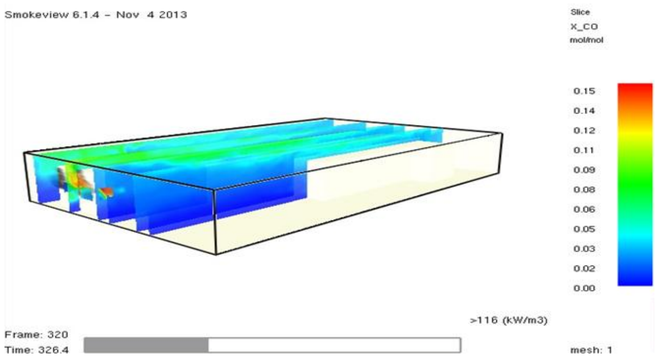


Fig 4.5 Level of CO inside the rest home at the flash over period

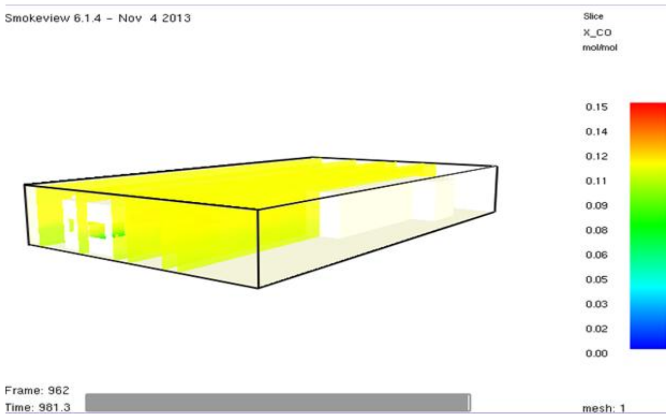


Fig 4.6 Level of CO inside the rest home during completely burning

One of the parameters produced during the fire incident is the increasing level of CO gas. CO gas produced as the result reaction of material properties which is polyurethane and the oxygen inside the building. This simulation result will indicate that most people died in the building is due to the smoke inhalation that consist of the CO gas.

4.2.2 Fraction Effective Dose analysis

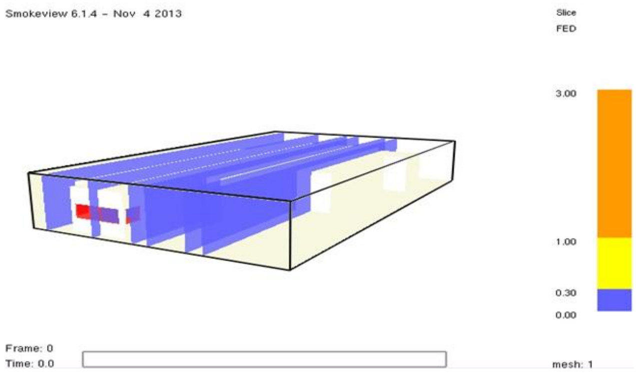


Fig 4.7 level of fraction effective dose at early stage

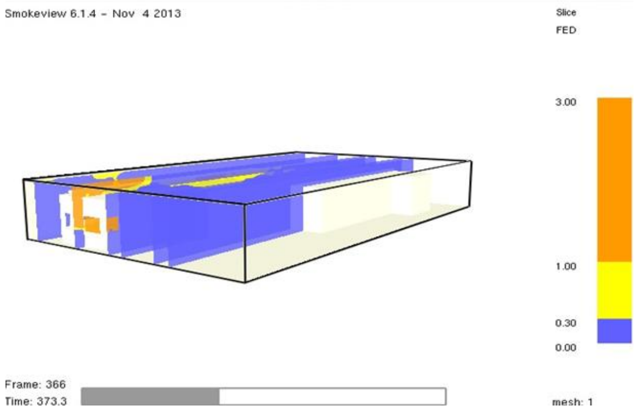


Fig 4.8 level of fraction effective dose at flashover

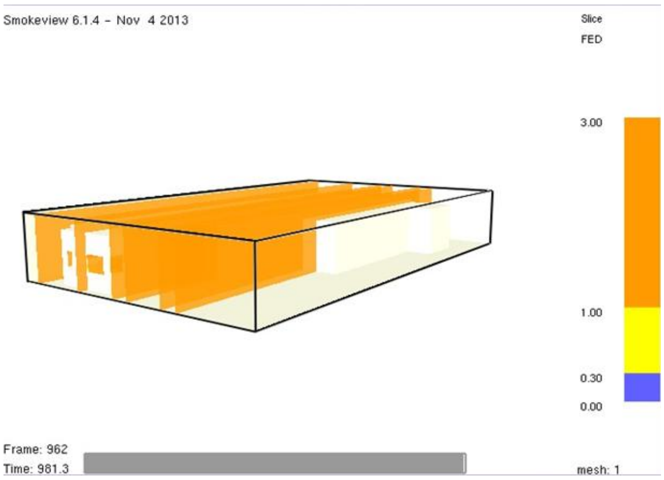


Fig 4.9 level of fraction effective dose at completely burning

FED (Fraction Effective Dose) is the important parameter to measure and as the indicator that represent the time that the people died due to the smoke inhalation. this fraction effective dose is vary between 0 to 3. As the value of fraction effective dose equal to 1, that will indicate the people is already died due to smoke inhalation.

4.2.3 Oxygen analysis

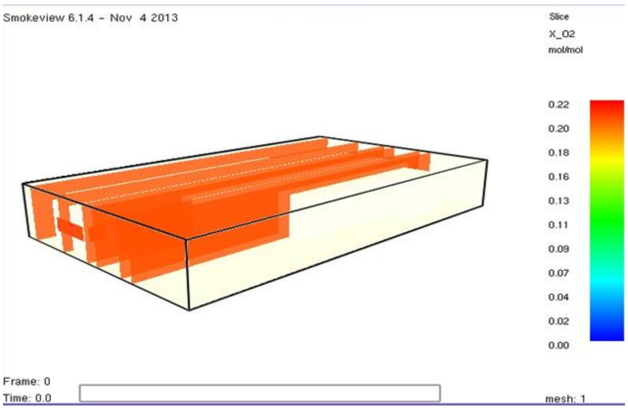


Fig 4.10 level of Oxygen gas, O_2 at early stage

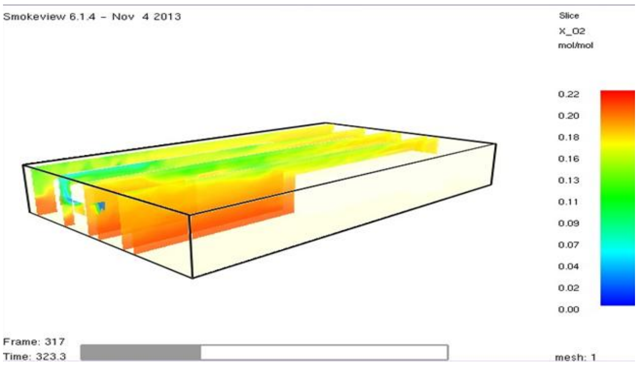


Fig 4.11 level of Oxygen gas, O_2 at flashover period

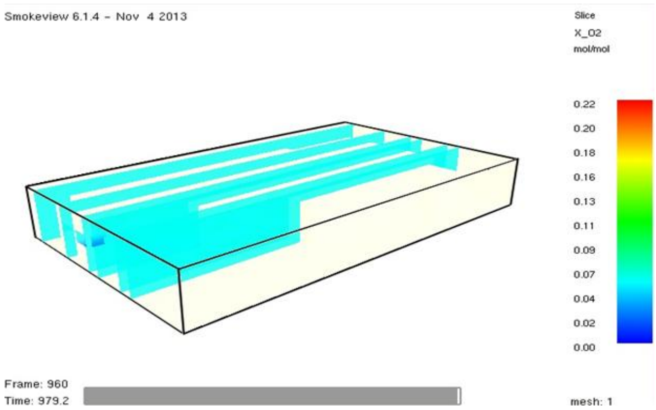


Fig 4.12 level of Oxygen gas, O_2 at completely burning

Presence of O_2 or Oxygen Gas. Oxygen gas play an important role in maintaining the fire. The level of Oxygen gas inside the building start to decrease as at the 323 seconds as it is in flashover period. This is due to development of fire during flashover period. Simulation of this parameter is crucial as indicator for window breaking due to the increase in heat release rate from the fire incident.

4.3 DISCUSSION

Fire incident is one major incident that contribute to increase in fatality. There are 3 element which are presence of oxygen, fuel and the source of heat necessary need for the fire to start ignite. Other parameter such as material properties, arrangement of material and the building dimension and specification will affecting in fire growth. This part will discussed about those parameter that affecting the growth of fire and also the analysis of fire simulation result of the fire dynamic simulator. The result is then compared to the investigation report of fire incident for the result validation process.

4.3.1 Parameter

<u>Arrangement of material</u>

Fire incident in Terwindle rest home is cause by the burning of 10 upholstered couch that made from polyurethane foam padding and the synthetic fabric. This couch is located in the lounge where first fire starting point happened. The arrangement of these 10 upholstered couch play an important role in leading to the flashover period as all 10 couch is completely ignited. This parameter will related on how fast fire is spread up as fire is one from of heat and heat can transfer either through convection, radiation and conduction. In this case, the arrangement of the material in terms of distance travel is one of element used in calculating the radiation of heat flux from one couch to the other couches in the lounge.

$$\dot{q} = \frac{X\dot{Q}}{4\pi R_o^2} \tag{4.3}$$

where $\mathbf{R^2}$ is the radius between couches or the distance from source of main heat release rate

<u>Material properties</u>

The properties of material will affecting the time taken for the fire to growth. These polyurethane foam padding consist of four element which are nitrogen, carbon, hydrogen and oxygen. Upholstered couch with polyurethane foam padding is categorized under fast of fire growth rate. The growth time and the fire intensity coefficient ,α is 150 seconds and 4.66 X 10^{-5}. This data will indicate that the fire incident happened in the Terwindle Rest Home is in fast growth rate.

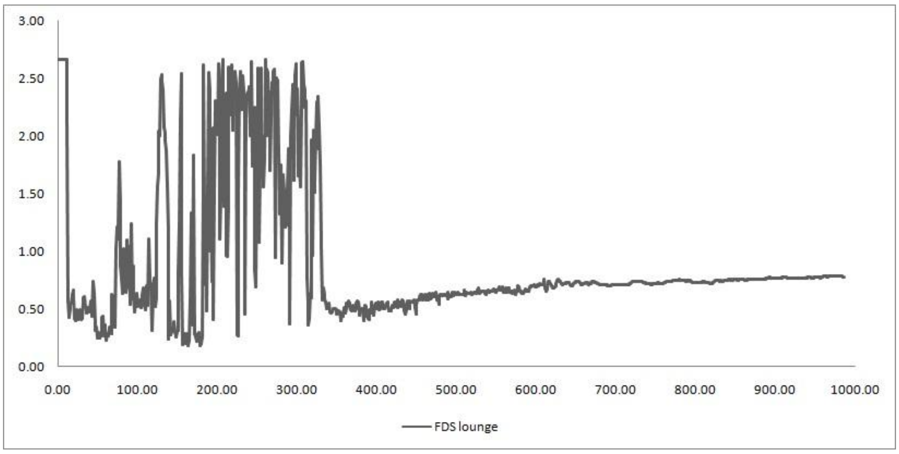
$$t_{ig} = \frac{338}{\dot{q} - 7.8} \tag{4.3}$$

where $\dot{q}$ is the radiated heat flux for specific material to start ignite.

4.3.2 FDS modeling

Analysis the Level of Carbon Monoxide and the fraction Effective dose

Analysis of Carbon Monoxide gas is done to validate the result whether most of people inside the building died due to the smoke inhalation. The level of the Carbon Monoxide gas or CO gas started to increase at the time 323 seconds during the flashover period. At this period, smoke produced the burning of all ten couches is spread throughout entire building and when the time reach 780 seconds, all the space inside the building is already full with the smoke. Based on the fire incident, there were 7 causalities during the fire incident and six of the deceased were male and one female.



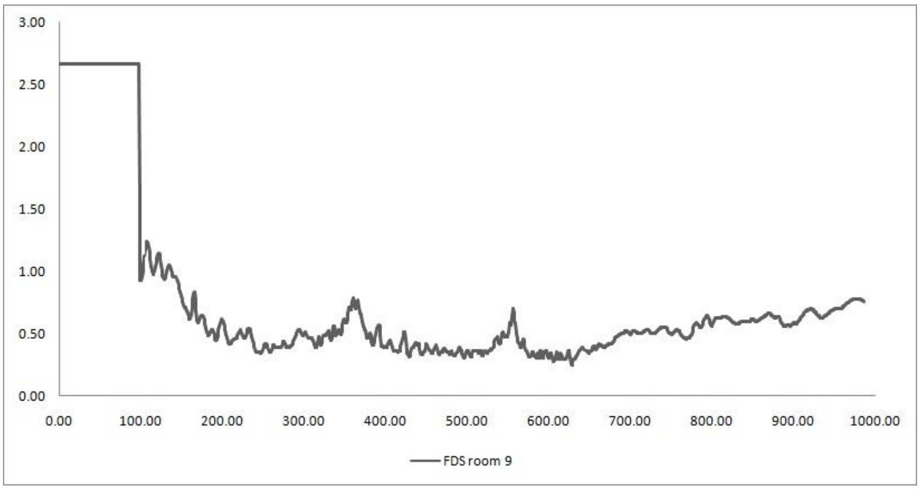


Fig 4.13 Smoke layer height at Lounge and Room 9

Figure 4.13 showed the graph smoke layer history in the lounge and room 9. Based on the graph, the smoke layer height continues to decrease in lounge and room 9 (same with other room), till 120 second. At this moment, the window at the lounge were broken due the insufficient of oxygen to maintain the fire incident which result in increasing the smoke layer height of the building. At the lounge (where the fire occurred) the smoke layer height increased after the window brakes and reached approximately 1.8m. In bedroom 9, the smoke layer height recorded slight increase when the widows break. However, the layer height at the bedroom decreased till it reaches range between 0.4m to 0.8m height. This is attributed to the fact that the windows at the bedrooms were opened during the fire. Hence the smoke continues flowing through the door opening, accumulated in the bedroom and certain of smoke is flowing outside the window which resulting in continuous increase in the layer height at the bedrooms.

FED (Fraction Effective Dose) is the important parameter to measure and as the indicator that represent the time that the people died due to the smoke inhalation. this fraction effective dose is vary between 0 to 3. As the value of fraction effective dose equal to 1, that will indicate the people is already died due to smoke inhalation. From the simulation. the value of fraction effective dose started to increase at the time of 323 seconds and the value of faction effective dose is equal to 3 when the time of 767 seconds. This simulation will support the simulation result of the carbon monoxide as most people already died due to smoke inhalation.

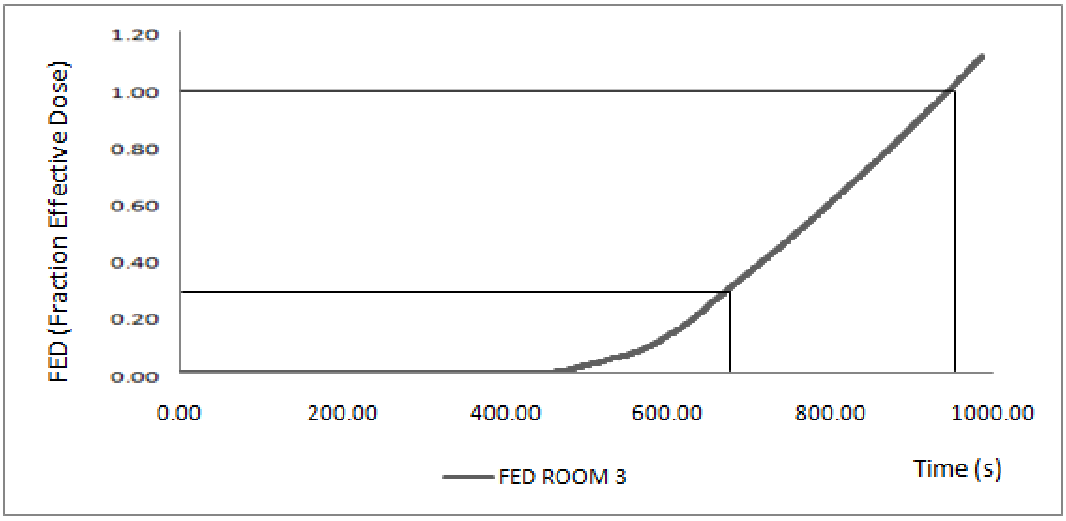


Fig 4.14 Level of Fraction effective dose in bedroom 3

Figure 4.14 shows Fraction Effective Doses (FED) for gases in bedroom 3. The FED shown here is at height of 1m where the residence sleeping height is approximately 1m above ground. The British standard published document (PD 7974-6, 2004) mentioned that the maximum allowed accumulated FED value should be 0.2, however (Purses, 2002) mentioned that when FED are summed during the exposure until the fraction reaches unity, this is when the toxic effect is predicted to occur.

Based on the graph above, it shows that the FED 0.3 value was reached in bedroom 3 at the 700 second from the fire growth which is approximately 11 minutes whereas the FED 1.0 value reached in the bedroom 3 at the 970 second approximately 16 minutes from fire growth . Based on the table in the investigation report (Byrne, 1994), the expected time when the fire started growing around 9.43pm (time zero in Figure 9). It can conclude that the FED of 0.3 value was reached at 9.54pm, whereas FED of 1.0 value was reached at 970 second after the fire growth (approximately 10pm). When the value FED reaches 1, it indicated that all the people inside already died. From this data, it can concluded that the FED value that indicate the occupant died and the timing showed in the table of the Terwindle Rest Home fire Investigation report can be acceptable with the approximate time scale of the progress of the fire and death timing shown in Figure 1. This shows that the CFD software can be use to model real fire which can be used to carry out investigations to know what happen during the fire incident as well as the predict the growth of fire incident. The simulation result also proved and has been acceptable as it is already validate against the real fire investigation report.

Value of FED (Fraction Effective Dose) which indicate people or occupant died is based on the level of toxicity gases produced during the fire incident and it is based on the below formula :

$$FED = (FIco+FICN)\ X\ VCO_2 + FIO_2 \quad (4.4)$$

This parameter can be minimized or decrease by reduce and control the development of fire. This can be done by installing fire controlling devices such as sprinkler and smoke separation door. Sprinkler is used to control and suppress fire by injecting the water onto the fire. As a result of reaction between the fire and the water, less toxicity gases produced. Hence, the level of FED will decrease. Smoke separation door will help in delay the smoke spreading throughout entire building. This will eventually give some amount of time to the occupant to evacuate themselves from the building.

CHAPTER 5

CONCLUSION

Fire investigation is need to be done in order to justify and to find out the actual phenomena happened during the fire incident. Terwindle Rest Home fire incident is remodelled and simulated using Fire Dynamic Simulator which one of the Computational Fluid Dynamic technique. The design fire incorporated into the CFD model was based on the measured heat release rate of a sofa at a Calorimetry lab. The total heat release rate of all couches at the lounge was calculated using radiation heat transfer and it is found that the peak heat release rate of each sofa which categorized into A, B, C and D depending on the arrangement was not reached at the same time. The model has been validated against the approximate time scale of the progress of the fire as it was found from the witness, NZFS call centre records, and the medical reports of the deceased.

From the fire simulation using the FDS, it showed that Fraction Effective Doses reached the value of 1.0 at 970 second which is 16 minute from the fire growth. By comparing to the expected time when the fire started to grow, it is approximately around 10.00 p.m. which indicated that all the occupants already died based on the FED value. From this data, it can concluded that the FED value that indicate the occupant died and the timing showed in the table of the Terwindle Rest Home fire Investigation report can be acceptable with the death time is between 10.00 - 10.15 p.m. The simulation shows that CFD software of fire Dynamic Simulator can be utilised in fire investigation provided that the correct design fire is used. From the simulation also, it is found out that lot of deficiencies in the building such as the door connect to the corridor is not smoke separation door which cause smoke to accumulate throughout the building, There were also no smoke detector system or sprinkler that can control and suppress the growth of fire which result in flashover within short time period.

RECOMMENDATION

Although fire incident is considered as one of most destructive incident, a proper precaution or taking measure of environmental safety can be done in order to prevent the fire incident. There are few of recommendation for the safety precaution in preventing the fire incident. One of the recommendations is by installing smoke detector and an alarm which can raised at least 25 minutes earlier. These two device is very crucial as it can give a warning to the occupant in the building that there was a fire incident happened during that time. Installation of smoke extraction will also helpful to the occupant as their visual will not be block by the block smoke due to the fire incident.

Another recommendations is to connect the smoke detector and the manual alarm to the fire service department. During the fire incident, every occupant will become panic and they will only think on how to evacuate from the building. As a result, a time lagging on arriving of the fire service department due to the late information received by the department. By installing these type of connection, the fire service department will get to know as soon as possible if there is any case of fire incident happened.

Limiting on the flammability and early fire hazard indices of material and furnishings can be one of the way in preventing the fire incident. By reducing the number of flammable material will eventually reduce the probability of the fire incident to occur in the building. The last recommendation is modifying the building by improve the safety precaution towards the fire incident. This can be done by using the resisting material as the material for designing the building. This can be utilized on the ceiling, wall and also door. As a result the growth of fire can be controlled and delayed which give more time for the occupants to evacuate themselves from the building.

REFERENCES

1. M. Nasif, R. Al-Waked, K. A. Nasser, M. K. Badran, Terwindle rest home fire investigation and code compliance, 3rd SFPE-SAC Fire Technology Conference, Saudi Arabia, 2010.
2. Byrne, P., 1994, Terwindle Rest Home – Fire analysis computer simulation, New Zealand Fire Service, Wellington, New Zealand
3. Chen, F. F., 2001, Radiant Ignition of New Zealand Upholstered Furniture Composites, Master of Engineering in Fire Engineering Thesis, The University of Canterbury, New Zealand.
4. Hall. J.R, 2011, Fatal Effects of Fire, National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471, www.nfpa.org
5. Spearpoint, M J (ed), 2008. “Fire engineering design guide” Centre for Advanced Engineering, Third Edition, University of Canterbury, New Zealand.
6. Ibrahim, 2012, International, Fire Safety: The way forward and Challenges ahead, Fire Conference and Exhibition Malaysia.
7. Gritch T and Eason B., 2009, Building envelope design guide – atria system. Whole Building Design Guide. National Institute of Building Sciences. Washington.
8. Ho, C.L., 2010, Simulation of Smoke Contamination in Upper Balcony by a Channelled Balcony Spill Plume in an Atrium, MSc Thesis.
9. Klote J. H. and Milke J. A., 2002, Principles of Smoke Management, American Society of Heating, Refrigerating and Air-conditioning Engineers, Atlanta.
10. Karlsson, B., Quintiere, J. G, 2000. “Enclosure fire dynamics”. CRC Press, USA.
11. Wade, C.A., 2004, A User’s Guide to BRANZFIRE, Building Research Association of New Zealand
12. M. Nasif, R. Al-Waked, 2013, "Using Computational Fluid Dynamics Simulation to perform fire investigation", Applied Mechanics and Materials Vol. 393, pp 845-850
13. Chi, J. H., Wu, S. H., Shu, C. M. , 2011, “Using Fire Dynamics Simulator (FDS) to Reconstruct a Hydroelectric Power Plant Fire Accident “, Journal of Forensic Sciences, Vol. 56, No. 6, pp. 1639-1644.
14. Shen T.S., Huang Y.H., Chien S.W.,2008, Using fire dynamic simulation (FDS) to reconstruct an arson fire scene. Build Environment, 43:1036-45

15. J.H. Klote, J.A. Milke, 2002, Principles of Smoke Management, American Society of Heating, Refrigerating and Air-conditioning Engineers. Atlanta.
16. S.A, Hasnain, M. Nasif, W. Pao, R. al- Waked 2014, " Numerical investigation on the effect of down stand structure in fire compartment on smoke contamination atrium upper balconies.", Applied Mechanics and Materials Vol. 465-466, pp 480-484.
17. K.McGratton, R.McDermott, S.Hostikka, J. Floyd, 2010, "Fire Dynamics Simulator (Version 5) User's Guide ", NIST Special Publication 1019-5
18. PD 7974-6, The application of fire safety engineering – Principles to fire safety design building- human factors: Life safety strategies- occupant evacuation, behaviour and condition, 2004, British Standards.
19. D. A. Purser, 2002 Toxicity Assessment of Combustion Products, Chapter 2-6, SFPE Handbook of Fire Protection Engineering, Third Edition, Society of Fire Protection Engineers, USA
20. Heskestad, G, 2002, Fire plumes, flame height, and air entrainment, Chapter 2-1, SFPE Handbook of Fire Protection Engineering, Third Edition, Society of Fire Protection Engineers, USA.

APPENDIX

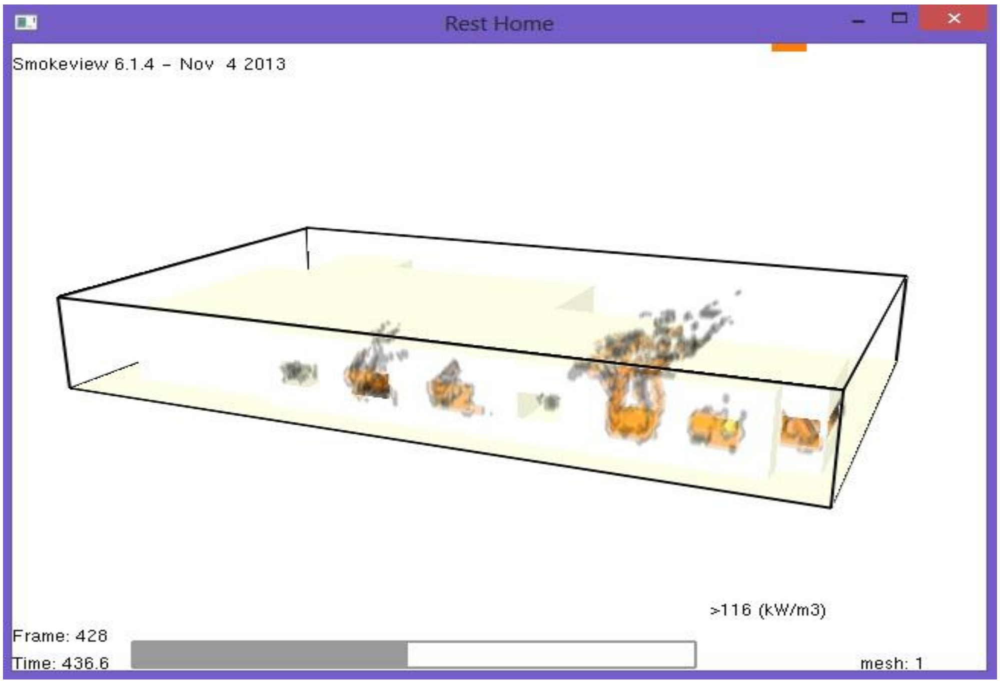


Fig 1 FDS fire simulation

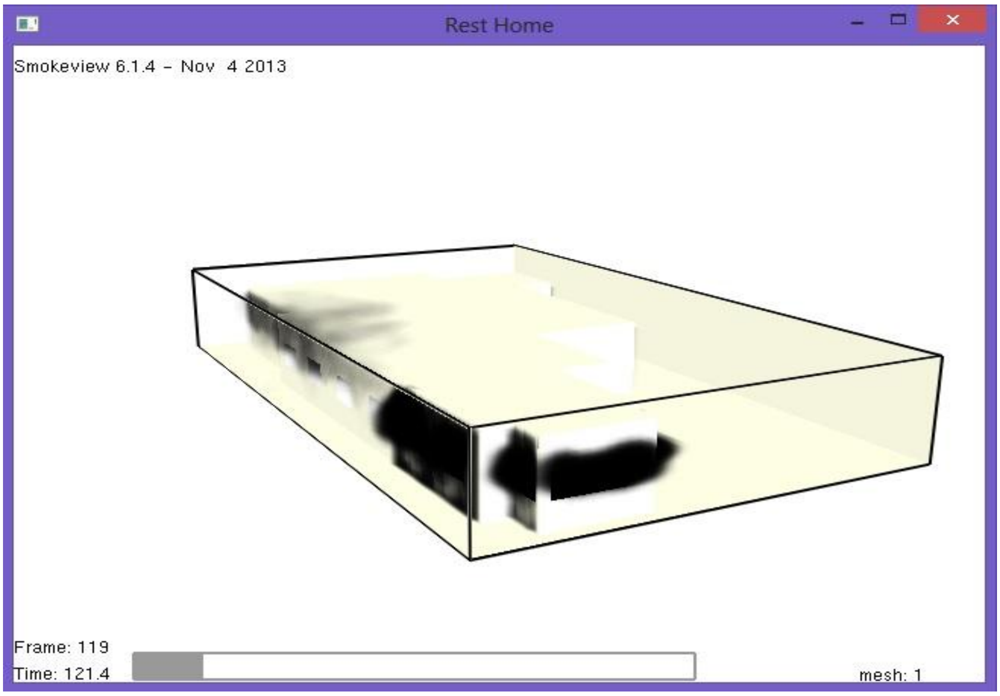


Fig 2 Smoke simulation (window braking)

Key milestone

Event or Deliverable	Target Date	Responsibility
	1^{st} Semester 2013	
Project charter/draft preparation	Week 1-5	Draft the feasibility and important of the topic with UTP supervisor
Project plan complete	Week 5-7	Draft the project planning and project activities
Project Research	Week 3-14	Research on literature Review
	2^{nd} Semester 2013	
Project execution initiated	Week 1-11	Conduct all the project activities as planned in the project deliverable
Project execution completed	Week 11-12	Complete the final documentation and ready for project deliverable
Supervisor acceptance	Week 13-14	Oral presentation of the topic and evaluation from UTP evaluator and UTP supervisor
Project closed out	Week 14	Hand in the final documentation for further reference to UTP and supervisor