Faculty of Mechanical Engineering

ANALYSIS OF AIRFLOW DISTRIBUTION AND THERMAL ENVIRONMENT IN LECTURE THEATRE BY COMPUTATIONAL APPROACH

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DELARATION

I declare that this thesis entitled "Analysis of Airflow Distribution and Thermal Environment in Lecture Theatre by Computational Approach" is the result of my own work except as cited in the reference. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :……………………………..

Author : **NUR FARAHIN BINTI MOHD AHADLIN**

Date : ……………………………….

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of Master of Mechanical Engineering (Energy Engineering).

Signature	:……………………………..
Name of supervisor	: **PM DR. TEE BOON TUAN**
Date	: ……………………………….

DEDICATION

To my beloved mama and abah

Also to my lovely husband, a handsome son and a pretty daughter

ABSTRACT

The indoor airflow distribution is the most important criteria as it will affect the thermal comfort of the occupants. This project is mainly focusing on modeling for temperature and velocity based on without and full occupancy inside lecture theatre. The simulation solution process be made up of modeling and meshing the basic geometry of the lecture theater using the ANSYS Fluent 16.0 CFD software. The intention of the project is to develop a Computational Fluid Dynamics (CFD) model that can describe the indoor airflow distribution with different number of occupancies setting in a lecture theatre and propose a suitable thermal condition for lecture theatre based on thermal comfort and environment. Many considerations have been taken to design this lecture theatre. The lecture theatre is designated with the length of the hall is 20.87 m, height 2.78 m and width 8.73 m. The velocity of the centralized air-conditioned system was setup by limitation of Malaysia Standard MS1525:2019 and varied between $v = 0.5\, m/s, 0.3\, m/s, 0.15\, m/s$ and constant temperature which is 24℃. The results demonstrate how temperature and velocity varies depending on the range of velocity setup. The airflow inside lecture theatre was forced to be spinning and rotating manner. The results performed be able to analyses which velocity setup is preferable. Based on the calculated value in the lecture theatre of the simulation, $V_{0.5m/s} = 0.1896\, m/s$, $V_{0.3m/s} = 0.1762\, m/s$ and $V_{0.15m/s} = 0.1654\, m/s$ which is decreasing manner. The average temperature distribution inside lecture theatre with fully occupied is also decreasing.

ANALISIS TABURAN ALIRAN UDARA DAN PERSEKITARAN TERMA DALAM DEWAN KULIAH DENGAN PENDEKATAN PENKOMPUTERAN

ABSTRAK

Taburan aliran udara dalaman adalah kriteria terpenting kerana ia akan mempengaruhi keselesaan termal penghuni.Projek ini menumpukan pada permodelan suhu dan had laju berdasarkan tanpa penghuni dan penghuni penuh di dalam bilik kuliah. Proses penyelesaian simulasi melibatkan pemodelan dan menggabungkan geometri asas teater kuliah menggunakan perisian ANSYS FLUENT 16.0. Matlamat projek ini ialah untuk melaksanakan model analisis Pengkomputeran Dinamik Bendalir yang dapat menggambarkan taburan aliran udara dalaman dengan jumlah penghuni yang berbeza di bilik kuliah dan mencadangkan keadaan termal yang sesuai untuk bilik kuliah berdasarkan keselesaan terma dan persekitaran. Beberapa pertimbangan diambil untuk merancang bilik kuliah ini. Bilik kuliah dibina dengan kepanjangan bilik kuliah adalah 20.87 m, tinggi 2.78 m dan lebar 8.73 m. Had laju sistem penyaman udara berpusat ditetapkan mengikut Malaysia Standard MS1525:2019 dan pelbagai had laju dari v=0.5 m/s, 0.3 m/s, 0.15 m/s dan nilai suhu yang sama iaitu 24℃. Keputusan menunjukkan bagaimana variasi suhu dan had laju bergantung pada jangkauan penyediaan halaju. Aliran udara di dalam bilik kuliah dipaksa berputar. Hasil yang diperoleh dapat digunakan untuk menganalisis pengaturan had laju mana yang lebih baik. Berdasarkan nilai yang dikira di dalam bilik kuliah dalam simulasi, had laju setiap persediaan $\mathrm{V}_{0.5\mathrm{m/s}} = 0.1896\ \mathrm{m/s}$, $\mathrm{V}_{0.3\mathrm{m/s}} = 0.1762\ \mathrm{m/s}$ and

$V_{0.15m/s} = 0.1654\ m/s$ *yang mana semakin berkurang. Taburan suhu purata di dalam dewan kuliah dengan keadaan penghuni penuh juga adalah menurun.*

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Bismillahirrahmanirrahim,

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LIST OF ABBREVATIONS

CFD	Computational Fluid Dynamics
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
MS	Malaysian Standard
DOSH	Department of Occupational Safety and Health
IAQ	Indoor Air Quality
ICOP	Industry Code of Practice
PPS	Pusat Pengajian Siswazah
UTEM	University Technical Malaysia Malacca
MAA	Mean Age of Air
TC	Thermal Comfort

LIST OF SYMBOLS

T	-	Temperature
Δ	-	Increment
%	-	Percent
$\dot{m}$	-	Mass flow rate
L	-	Length
v	-	Velocity
ϕ	-	Relative humidity
℃	-	Degree Celsius
$\in$	-	Epsilon
ρ	-	Density

CHAPTER 1

INTRODUCTION

1.1 Background

The lecture theatre is a large-scale room used for teaching at Pusat Pengajian Siswazah (PPS), UTeM based on Figure 1.1. In contrast to a common classroom with a capacity typically between one and fifty, the capacity of the lecture theatre is generally estimated by 130 occupants (students). The lecture theater has a pitched floor, so that those at the back are sitting higher than those at the front (i.e. tiered seats) so that they can see the lecturer. A large stage is located in front of the room, serving as a central point for the delivery and control of content. This lecture theater is designed to meet the visual communication needs of a modern classroom.

Figure 1.1: Lecture theatre in PPS UTeM.

Using the energy of airflow simulation is done by using a software that essentially represents a lecture theater design and conducts physical calculations for the distribution of airflow and the thermal environment inside the lecture theatre. The simulations may range from a construction component to a building cluster. The lecture theater model along with the use pattern and the local weather is required to determine different outputs such as peak loads, device size and energy consumption over a given period for a computational approach using the CFD (Computational Fluid Dynamics). These data can be used for estimating the cost-benefit analysis of different design strategies by evaluating utility bills.

Airflow simulation may contribute to the evaluation of different design strategies. The first tools are early design choices whereas decisions like the layout and configuration of the building are introduced in the early design stage. However, due to the limited information available at this stage, a detailed simulation may not be possible. The second tool is a simulation assist in decision-making while selecting individual components of the structural envelope or systems. Components or material selection are very important because it is used quite often to analyze various designs and components for cost-effectiveness. Consequently, modeling must be done with greater precision compared to modeling for early design decisions at this stage. The final tools are the retrofit decisions: energy simulation will help to evaluate cost-effective solutions for retrofitting existing buildings. The simulation model should be calibrated using the assessed building performance data for an accurate analysis.

The systematic approach can be used to simulate the energy of buildings. Many data are necessary. The necessary data should be collected before modeling begins. Location and weather files are the following basic information required. In the worksite, tools for energy simulation require hourly environment conditions (temperature, humidity, wind, velocity, solar radiation, etc.). In weather files, the information is available to extract the hourly ambient conditions during the simulation. However, the weather file may not be available for some locations such as Pusat Pengajian Siswazah,PPS at University Teknikal Malaysia Malacca (UTeM). The weather data from a different location may be used in such cases with similar weather conditions.

Different formats of weather files are available. Different tools use various formats for simulation. Various weather file formats are used by different simulation tools. Utilities can be found from one format to another on the web to convert weather files.

1.2 Problem Statement

Indoor air quality is a key concern for businesses, operators, occupants and employees, as it can affect building workers' safety, comfort, well-being and productivity. Indoor air quality also shows how the health, comfort and working ability of a person can be influenced by indoor air. Which may involve temperature, humidity, mold, bacterium, low ventilation or other chemicals, but may not be limited. In the past, less attention has been paid to indoor air pollution compared to outdoor air pollution. By referring Department of Occupational Safety and Health Malaysia (DOSH), this has now become a matter of increasing public concern, partially due to modern indoor air pollution, the isolation of the indoor atmosphere and the investigation of the so-called disease construction syndrome from the natural outside environment in well-sealed buildings.

Low air quality indoors can lead to inconvenience, ill health and absenteeism at work, as well as lower productivity. Good indoor air quality ensures the health and well-being of the building's occupants. Like Legionnaire’s' Disease, Lung Exposure Cancer and Carbon

Monoxide (CO) pollution, which is well known and severe health impacts resulting of bad indoor air quality (IAQ). More common health effects include the hypersensitive and asthma caused by exposure to indoor pollutants (especially building damp and mold), colds and other air-borne infectious diseases, and symptoms of 'Sick Building Syndrome' due to higher indoor pollutant rates together with other indoors. Such wider-ranging effects may affect large numbers of building workers and are related to high costs due to benefits, sick leave and loss of productivity.

Figure 1.2: Characteristic of High Performance Buildings.

1.3 Objectives

The objective of this research is as follow:

1. To establish CFD model that can describe the indoor airflow distribution and environment in a lecture theatre.

2. To investigate the indoor condition with 130 number of occupancies setting by using CFD.
3. To propose a suitable thermal condition for lecture theatre based on airflow distribution and environment

1.4 Scopes of Project

The scopes for this project are:

1. Analysis of the airflow distribution and thermal environment in the lecture theatre.
2. CFD Simulation is optimized for with and without occupancy inside the lecture theatre.
3. Analysis in 3D (3 dimensional) in steady state condition.

1.5 Hypotheses/ Research Questions

1. How to perform the indoor airflow distribution inside the lecture theatre at PPS UTeM by using Computational Fluid Dynamic (CFD) software?
2. What is the best indoor thermal conditions inside the lecture theatre with and without occupancy in the lecture theatre?
3. How does the maximum number of load occupancy inside the lecture theatre to be occupied affect an indoor airflow distribution affect?

1.6 The Importance of the Project

1. The study of scientific literature on indoor airflow distribution systems and ventilation performance using CFD software.

2. Identify and determine the most relevant room temperature and velocity of air flow distribution systems in compliance with the Malaysian Standard MS1525:2019 limit.