THERMAL COMFORT OF A TYPICAL OFFICE BUILDING: A PARAMETRIC INVESTIGATION

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DECLARATION

I declare that this project report entitled "Thermal Comfort of a Typical Office Building: A Parametric Investigation" is the result of my own work except as cited in the references

Signature : …………………………

Author : …………………………

Date : …………………………

SUPERVISOR'S DECLARATION

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 the degree of Bachelor of Mechanical Engineering with Honours.

Signature : …………………………

Name of Supervisor : …………………………

Date : …………………………

DEDICATION

To my beloved mother and father

Acknowledgement

Foremost, I would like to acknowledge and express my sincere appreciation to those who has provided me the assistance to complete this project. Without their help and support, this project would not have been successfully completed.

First of all, I would like to take this opportunity to express my deepest appreciation to my supervisor, Dr Tee Boon Tuan, for his professional knowledge and help in assisting me to complete my project. His patience, guidance and advices in guiding me through this project was greatly appreciated.

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Abstract

Air temperature and air velocity distribution are important parameters that can affect the thermal comfort level of the occupants in the building. The main purpose of this study is to investigate the air temperature and air velocity distribution inside a typical office building. Ground floor and first floor of Mechanical Engineering Faculty (FKM) building are selected for this study. The air temperature and air velocity distribution for both floors were analyzed to determine the suitable air-conditioning setting configuration. Physical measurement and Computational Fluid Dynamics (CFD) are the two main approaches in this study. Physical measurement was conducted by using air velocity meter. CFD simulation was developed by using IESVE software. The air-conditioning temperature setting configuration which is able to maintain the acceptable thermal comfort level is determined. Besides that, the energy consumption for the configuration is also being calculated. The velocity setting configuration for BK 4, 5, 6, 8, 17 and PA are 3 m/s, 4m/s, 3 m/s, 3m/s, 3m/s and 4m/s respectively. The temperature setting configuration for BK 4, 5, 6, 8, 17 and PA are 22 ºC, 21 ºC, 21 ºC, 22 ºC, 21 ºC and 24 ºC respectively. The energy consumption for suitable settings is lower than non-suitable settings for both ground floor and first floor.

Abstrak

Taburan suhu udara dan halaju udara adalah parameter penting yang boleh memberi kesan kepada tahap keselesaan termal penghuni di dalam bangunan. Tujuan utama kajian ini adalah untuk mengkaji taburan suhu udara dan halaju udara di dalam bangunan pejabat yang tipikal. Tingkat aras bawah dan tingkat satu Fakulti Kejuruteraan Mekanikal (FKM) telah dipilih untuk kajian ini. Taburan suhu udara dan halaju udara untuk kedua-dua tingkat dianalisis untuk menentukan konfigurasi pelarasan penghawa dingin yang sesuai. Pengambilan data fizikal dan kaedah Pengkomputeran Dinamik Bendalir (CFD) adalah dua kaedah utama dalam kajian ini. Pengambilan data fizikal akan dijalankan dengan menggunakan meter halaju udara. Simulasi CFD akan dijalankan menggunakan IESVE. Konfigurasi suhu pelarasan penghawa dingin yang boleh mengekalkan tahap keselesaan termal yang sesuai ditentukan. Selain itu, kegunaan tenaga untuk konfigurasi tersebut juga turut dikira. Taburan halaju udara untuk BK 4, 5, 6, 8, 17 dan PA adalah 3 m/s, 4m/s, 3 m/s, 3m/s, 3m/s dan 4m/s. Taburan suhu udara untuk BK 4, 5, 6, 8, 17 dan PA adalah 22 ^{o}C, 21 ^{o}C, 21 ^{o}C, 22 ^{o}C, 21 ^{o}C dan 24 ^{o}C. Kegunaan tenaga untuk konfigurasi yand sesuai adalah lebih rendah daripada konfigurasi yang tidak sesuai untuk kedua-dua tingkat aras bawah dan tingkat satu.

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List of Symbols

Symbols	Description
T_{comf}	Comfort Temperature
^{o}C	Degree Celcius
ε	Epsilon
α	Griffiths' constant
T_a	Indoor Air Temperature
V_a	Indoor Air Velocity
T_g	Indoor Globe Temperature
K	Kelvin
m	Meter
m^2	Meter Square
T_o	Outdoor Temperature
Pa	Pascal
%	Percentage
s	Second
Σ	Summation
T	Temperature
Θ	Theta
W	Watt

List of Abbreviations

Abbreviations	Description
ADPI	Air Diffusion Performance Index
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BK	Bilik Kuliah
CATIA	Computer Aided Three dimensional Interactive Application
CFD	Computational Fluid Dynamics
CFM	Cubic Feet per Minutes
CL	Mechanical Cooling
Clo	Clothing Unit
CO	Carbon Monoxide
CO_2	Carbon Dioxide
FKM	Fakulti Kejuruteraan Mekanikal
FPM	Feet per Minutes
FR	Free-Running
H	Height
HVAC	Heating, Ventilation, and Air-Conditioning
IEQ	Indoor Environmental Quality
IESVE	Integrated Environmental Solution- Virtual Environment
IGSES	Interdisciplinary Graduate School of Engineering Science
KU	Kyushu University
L	Length
MET	Metabolic Rate

MRT	Mean Radiant Temperature
MS	Malaysian Standard
PA	Postgraduate Area
PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfied
PSM	Projek Sarjana Muda
RH	Relative Humidity
RPM	Revolutions per Minutes
TNB	Tenaga National Berhad
UFAD	Under-Floor Air Distribution
UiTM	Universiti Teknologi MARA
UTeM	Universiti Teknikal Malaysia Melaka
UTM	Universiti Teknologi Malaysia
W	Width

CHAPTER 1

INTRODUCTION

With the rising of awareness about maintaining good indoor environmental conditions, there are more and more people started to emphasize the importance of indoor thermal comfort. Indoor thermal comfort in general can affects occupants' comfort and this will further influence their emotional condition as well as productivity (Youssef et. al, 2015)

As defined by ASHRAE Standard 55-2010, thermal comfort is the occupants' satisfaction towards surrounding thermal conditions. Thermal comfort is used to determine whether the surrounding condition is in the occupants' acceptable range or not. Air temperature, metabolic rate, clothing insulation, radiant temperature, air velocity and humidity are the six primary factors that must be stated when defining thermal comfort level.

As the location of Malaysia is near to the equator and expose to sun. The country has a warm and humid climates condition throughout a year. Due to the high average air temperature, most Malaysia citizens choose to install a mechanical cooling system such as air-conditioning in order to achieve suitable indoor thermal comfort level (Zr & Mochtar, 2013).

As more and more buildings in Malaysia rely on mechanical cooling system, the average energy usage goes up as well. According to Hassan et. al (2014), 48% out of the total electricity generated in Malaysia consumes by buildings. Meanwhile, more than 50% of the electricity is used by mechanical cooling systems to provide suitable thermal comfort level to occupants. Hence, it can be seen that there is a huge potential in energy saving by optimizing the usage of mechanical cooling systems such as HVAC (Heating, Ventilation and Air Conditioning).

With the advancement of computer technology, Computational Fluid Dynamics (CFD) has becomes a popular tool to visualize and predict the motions of gas or liquids. CFD already exists since early 20th century which enables users to simulate complex fluid motion by using a computer. As explained by Chen (2009), about 70% of the researchers who study ventilation performance choose to use CFD in simulating the flow and temperature distribution in a building. Most of the indoor environment designs are getting more complicated and CFD comes in handy to predict the indoor thermal comfort.

CFD is widely used in everyday life to analyse the fluid flow such as meteorological phenomena, environmental hazards, HVAC industries, complex flows in furnaces, combustion in automobile engines and etc. Researchers do not need to perform difficult experiments hands on. They can obtained the simulation results as long as the physical data are available. This can save a lot of time as well as cost in performing experiments (Kuzmin, n.d.).

By optimizing the application of CFD, this project is aimed to simulate the current thermal comfort condition for university building.

1.1 Problem Statement

The main purpose of this study is to investigate the thermal comfort of UTeM's Faculty of Mechanical Engineering (FKM). A suitable and stable thermal comfort of the faculties is extremely important to students, lecturers, and staffs.

Humans are very sensitive to surrounding temperatures. According to the survey done by Izzat (2016), a majority of FKM's students feel that the surrounding temperatures is hotter and most of the temperatures level are beyond the acceptable range. The fluctuated temperature and air velocity distribution perhaps is due to the inefficient air-conditioning system of the building.

Air temperature and air velocity play an important role in thermal comfort. Optimizing air temperature and air velocity not only will provide thermal comfort, it will save the energy cost as well and reduce carbon dioxide emission. As mentioned by Tenaga Nasional Berhad (TNB) (n.d.), 24^{o}C – 26^{o}C is the optimum temperature to give the best thermal comfort in a building.

Hence, this project intends to find the answer for the following question:

a) How does the current setting for the air-conditioning system of the building affect the temperature and air velocity distribution?
b) Does the current thermal comfort level of the building within the acceptable standard?

c) What are the suitable air-conditioning system configuration in order to improve the current thermal comfort level and energy consumption?

1.2 Objective

i. To illustrate the changes of thermal comfort level under different circumstances and parameters by using the available building simulation software.
ii. To investigate the change in the energy demand of the case building in the different scenarios.

1.3 Scope

The scope of this study is to evaluate on the thermal comfort in a typical office building:

i. The study will be conducted in FKM building.
ii. The main parameters involved in the thermal comfort simulation are temperature and air velocity.
iii. The simulation will be conducted by using available CFD software.

1.4 The Importance of the Work

This simulation obtained in this investigation will give a good overview in term of temperature and air velocity distribution of the building, whether comply with the current standard or not. The information will be a good input for the building engineer or manager to find potential measures to improve the situation for the non-comply case. The modelling of the thermal comfort condition by using CFD software can provide another alternative in analysing indoor condition besides conducting actual measurement. The simulation result if applicable can be a benchmark for future building design at pre-design stage. The study also focuses on how different temperature and air velocity affect the outcome of thermal comfort as well as the changes in the energy demand for the different scenarios. Through the study, a typical office building can know the optimum indoor temperature and air velocity required for the building to provide suitable thermal comfort level can be determined. Thus, building energy consumption can be minimized through correct setting of air-conditioning temperature.