Faculty of Mechanical Engineering

OCCUPANTS' PERCEPTION TOWARDS THERMAL SENSATION IN ENGINEERING LABORATORY

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DECLARATION

I declare that this thesis entitled "Occupants' Perception Towards Thermal Sensation In Engineering Laboratory" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : NUR ADIBAH

Date : 7/08/19

APPROVAL

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

Signature :..

Supervisor Name : TEE BOON TUAN

Date : 9/8/2019

DEDICATION

I dedicate my project work to my family and my friends. A special feeling of gratitude to my father Mr Gulam Mahfuze bin Mobarak Ali and to my mother Mrs Farzana binti Muhammad Sarwer, who encouraged me and push for tenacity to improve myself throughout all my walks of life and who has always been with me in overcoming difficult times in my life. His patience is the meaning of love, kindness and gentle soul. Thank you for giving me a chance and I love my parents. I also dedicate this project to my siblings who have supported me through my life. I always miss and I cherish the memories that we had. I love all of you.

ABSTRACT

Thermal comfort can be defined as a state of mind that expresses satisfaction toward the surrounding thermal environment. European Standard ISO 7730 stated that thermal comfort is a combination of four environmental parameters such as air temperature, relative humidity, air velocity and mean radiant temperature. This study aims on measurement of thermal comfort at faculty mechanical engineering laboratory. There are two different laboratories that will be conducted in this experiment one with air conditioning (with and without occupants) whereas with no air-conditioning (with and without occupants). The procedure to determine occupant's responses toward thermal comfort in student laboratory is through observation method associated with a survey. Measurement of actual thermal comfort in student laboratory is accomplished through technical measurement associated with a thermal microclimate HD32.1. The overall average air velocity was recorded of the Fabrication Laboratory with occupant is 0.29m/s that is within the Malaysian standard but for other condition it was lower than Malaysian standard which is 0.064m/s. However, for the Computer Aided Design Studio with occupant is 0.48 m/s, within the Malaysian Standard MS1525:2014 (0.15 m/s – 0.50 m/s), while for without occupant is 0.11 m/s, less than the Malaysian Standard MS1525:2014 (0.15 m/s – 0.50 m/s). The overall average operative temperature was recorded of the Fabrication Laboratory for both condition is more than the Malaysia Standard MS1525:2014 (24 ℃ – 26 ℃) which are 30.88 ℃ and 30.7 ℃. Furthermore, the Computer Aided Design Studio also both condition were within the range of Malaysian Standard MS1525:2014 (24 ℃ – 26 ℃) which is 24.4 ℃ and 23.3 ℃.. The overall average relative humidity was recorded of the Fabrication Laboratory with occupant is 71.82 % more than the Malaysia Standard MS1525:2014 (50% – 70%), but for without occupant is 63.51 % within the range of Malaysian Standard MS1525:2014 (50% – 70%), while the Computer Aided Design Studio with occupant is 51.36 % and without occupant is 52.49 %, within the range of Malaysian Standard MS1525:2014 (50% – 70%). From the survey, occupants' are feel comfortable with both condition laboratory. For the future study, can study the effect of the solar heat gain with thermal comfort level, such as analysis in a laboratory with the variance, time and whether.

ABSTRAK

Keselesaan terma boleh ditakrifkan sebagai keadaan minda yang menyatakan kepuasan terhadap persekitaran terma di sekitarnya. Standard Eropah ISO 7730 menyatakan bahawa keselesaan terma adalah gabungan empat parameter alam sekitar seperti suhu udara, kelembapan relatif, halaju udara dan suhu berseri rata. Kajian ini bertujuan untuk mengukur keselesaan termal di makmal kejuruteraan mekanikal fakulti. Terdapat dua makmal yang berbeza yang akan dijalankan dalam eksperimen ini dengan penghawa dingin (dengan dan tanpa penghuni) manakala tanpa penghawa dingin (tanpa dan tanpa penghuni). Prosedur untuk menentukan tanggapan penghuni terhadap keselesaan haba di makmal pelajar adalah melalui kaedah pemerhatian yang berkaitan dengan tinjauan. Pengukuran keselesaan haba sebenar di makmal pelajar dicapai melalui pengukuran teknikal yang berkaitan dengan HD32.1 mikroklimat termal. Halaju udara purata keseluruhan dicatatkan dari Makmal Fabrikasi dengan penumpang adalah 0.29m / s yang berada dalam standard Malaysia tetapi untuk keadaan lain ia lebih rendah daripada standard Malaysia iaitu 0.064m / s. Walau bagaimanapun, bagi Studio Reka Bantu Sendiri Komputer dengan penghuninya ialah 0.48 m / s, dalam Standard Malaysia MS1525: 2014 (0.15 m / s - 0.50 m / s), sementara tanpa penghuni ialah 0.11 m / s, kurang daripada Standard Malaysia MS1525: 2014 (0.15 m / s - 0.50 m / s). Suhu purata suhu operasi yang dicatatkan di Makmal Fabrikasi untuk kedua-dua keadaan adalah lebih tinggi daripada Standard Malaysia MS1525: 2014 (24 °C - 26 °C) iaitu 30.88 °C dan 30.7 °C. Selain itu, Studio Reka Bentuk Komputer Dibantu juga berada dalam lingkungan Standard Malaysia MS1525: 2014 (24 °C - 26 °C) iaitu 24.4 °C dan 23.3 °C .. Purata kelembapan relatif purata dicatatkan Makmal Fabrikasi dengan penghuni adalah 71.82% lebih tinggi daripada Standard Malaysia MS1525: 2014 (50% - 70%), tetapi tanpa penghuni adalah 63.51% dalam julat Standard Malaysia MS1525: 2014 (50% - 70%), sementara Computer Aided Design Studio adalah 51.36% dan tanpa penghuni adalah 52.49%, dalam lingkungan Malaysian Standard MS1525: 2014 (50% - 70%). Dari kaji selidik, penghuni 'merasa selesa dengan kedua-dua makmal keadaan. Untuk kajian masa depan, dapat mengkaji kesan peningkatan haba matahari dengan tahap keselesaan termal, seperti analisis dalam makmal dengan varians, masa sama ada.

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LIST OF SYMBOLS

%	-	Percent
m/s	-	metre per second
°C	-	Degree Celsius
cm	-	Centimeter
Tw	-	Wet Temperature
Tg	-	Globe temperature
Ta	-	Air temperature
Pr	-	Pressure
Va	-	Air Velocity
RH	-	Relative humidity
Tr	-	Radiant temperature
PPD	-	Predicted percentages of dissatisfied
PMV	-	predicted Mean voted
hpa	-	hectopascal

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CHAPTER 1

INTRODUCTION

1.0 Background

Thermal comfort is a term that is generally considered to be reasonable or optimistic-state of somebody. It applied to represent the degree of warm or cold a person feels and is obviously associated with the atmosphere occupied by a person. To provide a comfort indoor environment to the occupants, Air conditioning (AC) and the ventilation systems should be installed in the building which can control the temperature. The improper control of relative humidity can cause the occupants to suffer from nausea, irritations of eyes, fatigue, and others that is called Sick Building syndrome (SBS) (Joshi, 2008). Different researcher underline that awful indoor condition conditions will expand the danger of sick building syndrome (SBS) side effects, poor comfort fulfilment level and medical problems (Amin, 2015). Indoor Air Quality (IAQ) is the important factor to produce the comfortable surroundings for the occupant's attention, concentration, learning, hearing and performance. When discuss about indoor air quality, the main important factor is thermal comfort (Yau, 2011). The improper thermal comfort will be given the negative impact on occupant's health.

Furthermore, indoor air quality and thermal comfort are the essential point, so that it can be considered and tended to by the building designer. The indoor air quality can be accessed by several parameters which is included carbon dioxide, concentration temperature and relative humidity (Elf, 2017). The health of the occupants can be affected by the dissatisfaction indoor air contains particles. The size, kind, and concentration of the particles that are contain in air need to be determine in order to ensure the health risk of occupants in a room (Vilhelm & Kvols, 2000). However the thermal comfort also have several parameters which is temperature, air velocity, and relative humidity (Amin, 2015). In this research, the focus will be on the occupants' perception towards thermal comfort in the laboratory of UTeM.

1.1 Problem Statement

From previous sources, some of the problems statements had found which relevant to the effects of thermal comfort or discomfort in the laboratory environment (Chaudhuri, 2018). Working in uncomfortably hot and cold environments are more likely to behave unsafely. It is also very important to know the actual situation of the indoor environment concerning temperature and relative humidity. A long side these Budaiwi (2007) state the undesirable thermal conditions can lead to occupant dissatisfaction, which in turn has an adverse effect on their health, productivity, and performance. There are also parameters that affect the sensation of heat that can contribute to increased learning productivity such as air temperature, radiant temperature, air velocity or airflow, and relative humidity. Learning productivity can affect the thermal environment with Sick Building Syndrome (SBS) symptoms. Humans are too sensitive to air temperatures and air velocities, especially when work productivity increases with higher airflow rates. Therefore, air conditioning (AC) is essential to improve human thermal comfort and their productivity in hot and humid climates. By implementing this case study in UTeM's laboratories, thermal discomfort can be prevent therefore students can performed at their best level. In the research field of thermal comfort, there have several important variable such as the human activity level, clothing insulation, mean radiant temperature and velocity of the indoor air quality. Those thermal variable will be the main parameters to assess the thermal comfort level in the student laboratories for this research.

1.2 Objective of Project

The main objectives of this research are:

i. To measure the thermal comfort parameters and analysis with occupants perception.
ii. To compare the analysis between the measurement parameters with the available standards such as ASHRAE: 55 (2017) and MS1525:2014.

1.3 Significant of Study

This study is focus on the effect and relationship between the thermal environment parameters and occupants' perceptual responses specifically for a very important engineering laboratory environment. This project can also provide data for physical parameter measurement consist of air temperature, relative humidity, air velocity and mean radiant temperature which can assist in thermal comfort study.

1.4 Scopes of Study

The scope of tis research are:

i. The report is present the analysis of thermal comfort parameters and will be analysis with occupant's perception. The measurement of analysis will be measured at the air-conditioning lab and non- air conditioning lab.

ii. The selected laboratory for this case study are Fabrication laboratory and Computer Aided Design Studio 1 (SRBK 1).

iii. The result will be compared with ASHRAE-55- 2017, MS1525.

1.5 Report organization

This study aimed to analyse the thermal comfort of UTeM Laboratories, through physical parameters and then compared with the current Malaysian standards (MS1525:2014).

Chapter 1 covers the introduction, objectives, significant, project planning and problem related to this study discussed in detail. Chapter 2 covers and discusses the fundamental theory issue of the study. However, this chapter will deal with the previous studies that is related to this study, it involves describing the concept for this study. Chapter 3 discusses the data gathered and describe the laboratory and more detail about the equipment used to measure the physical parameters. All data are explained and discussed in connection with the study project. Chapter 4 discusses the data gathered and the result acquired from the computation. All data are interpreted and discussed in connection with the research project. Collected as a result of measurement of physical parameters and will compare the proposed standards to evaluate their performance. Chapter 5 discusses conclusions and recommendations of this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Thermal Comfort

ASHRAE 55-2017 state the thermal comfort can be defined as a condition of mind which express satisfaction with the surrounding thermal environment. Indoor condition states of a building are one of concerned issues as individuals generally invest a large portion of their energy inside the structure

There are several parameters involved in thermal comfort such as temperature, humidity, air motion and side factor like dress and also occupant's activity level. The thermal comfort can be maintained when the human metabolism and the equipment that generated heat were dissipate. After that, the thermal comfort will be maintained with the surrounding. ASHRAE Standard 55 (2017) stated that operating temperature and humidity is accepted in summer when the temperature in the range 24 °C – 28 °C with 30% of relative humidity and 23 °C – 25.5 °C with 60% of the relative humidity and air speed of the below that 0.25m/s for 0.5 clo light clothing. However, if the value of humidity below than 50 % then can be contribute to the spreading of influenza virus and it will cause tissue weakness. When the discomfort situation happen by drying out the mucous membrane and can cause skin rashes. All workers will comfortable when the relative humidity at 50 %. The massive humidity will affect the surrounding feel stuffy. The bacterial and fungal can growth easily can sealed buildings (Yau, 2011)

2.1.1 Thermal Comfort Environment Factor

Based on ISO 7730, the level of thermal comfort can be determined by a combination of two personal factors plus four environmental parameters. Air temperature, mean radiant temperature, air velocity, and relative humidity are the four environmental parameters that have to be considered. The detail of four environment parameters had been designated as following:

i. Air temperature: The most crucial element in thermal comfort is the air temperature. There is no appropriate answer for —best temperature. The best temperature can be defined as the most people feel comfortable in a room. For general laboratory, 20–24°C is comfortable temperature for most people in winter when wearing winter clothes and 23–26°C in summer when summer clothes are being worn (Leitão, 2017). Temperature basically expressed in the Fahrenheit (°F) and Celsius (°C). The standard unit of temperature is Kelvin (K). Air temperature is important as it affects all weather parameters (Staff, 2010).

ii. Mean Radiant temperature: The average temperatures that surround a person are called mean radiant temperature. The most contribute in mean radiant temperature is the sunlight coming in through a window. By using a curtain and closing of blinds can helps decreased the amount of sunlight that going in a room. According to ASHRAE (2010), mean radiant temperature can defined as the uniform surface temperature of an imaginary block enclosure in which an occupant would have some radiation exchange as in the real environment.

iii. Air velocity: The speed of air movement in a student laboratory can be called as air velocity. Uncomfortable feeling can be occurred if the air velocity is at the peak position. The evaporation of sweat is directly proportional with the increasing of air velocity hence leading to a cooling effect, with the help of thin clothing. However, the air velocity becomes less important matter if the temperature or humidity is too high. Control the air velocity is the only solution to achieve physiological comfort at high temperature environment because it affects both evaporative and convective heat losses from the human body (Indraganti et al., 2012).

iv. Humidity: Indoor temperature and humidity are two important parameters that affect the thermal comfort of the building systems. (Katunky, 2013) found that the energy consumption is reduced by about (5.20-6.20) % increasing indoor temperature by 1 °C under the same relative humidity. Humidity affected the rate of evaporation of sweat, which affected the ability of the body to dissipate heat at higher ambient temperatures (Abed, 2012).

2.1.2 Thermal Comfort Individual Factor

The thermal comfort in buildings based on the individual factors has be describe by several sources as follows:

i. Clothing insulation: It is to protect human body against the hot and cold conditions. The amount of thermal provided by clothing strongly influenced the thermal comfort of a person inside a building as it prevents heat exchange between human body and environment. High insulation value of clothing means that lower heat exchange with the surroundings.

The expression is in unit clo units, which measure thermal isolation given by articles of clothing and apparel groups (Soni, 2013).

ii. Metabolic rate: The rate at which human body burns calories to produce the energy it needs function. Human with various physical characteristics have different thermal sensation and thus different desired thermal comfort level inside the building. High thermal sensation requires cooler indoor conditions to achieve comfort (Goto, 2002).

2.2 Predicted Mean Vote (PMV) and Predicted Percentages Dissatisfied (PPD) scales

These two scales has been describes as indices and specifies acceptable condition for thermal comfort in the ISO 7730 Moderate thermal environment. If the group people are large, then the PMV scale index will be used because it can provide the mean value of the vote by using 7-point thermal sensation by (Parsons, 1993). The PPD is an index that establishes a quantitative prediction of the percentages of thermally dissatisfied people determined from PMV. The PMV model using heat balance principles to relate the key of factors for thermal comfort parameters listed. A according to the ASHRAE standard-55, they recommended the PPD is below than 10 and PMV in the range of – 0.5 to + 0.5.

2.3 ASHRAE Standard-55 (2017)

ASHRAE 55 Standard is reflect the air quality (ASHRAE Standard, 2017). When the purpose of the standard it be remain consistent indoor air quality for the human occupants and health effects. However, it also be using to guide the improvement of indoor air quality of the others buildings. It also for regulatory application to new building, additions to existing buildings and those have any changing to existing buildings that are identified in the body of the standard. List below show some recommendation of indoor design condition of an air- conditioning:

i. Recommended temperature 22°C - 26°C.

ii. Recommended relative humidity 30% - 60%.

iii. Recommended air velocity 0.15 m/s.

2.4 Malaysian Standard MS1524:2014

Department of Standard Malaysia is a country of accreditation and standardisation bodies. Basic capabilities of the department is to promote and advance models, institutionalization and declaration as a tool to boost the country's economy, increase the productivity of industry and improvement, medical and wellness opened edge, secure shopping, promote exchange and global household and grew up in the universal connection measure and institutionalization (Halim, 2006).

Since the atmosphere of Malaysia, is consider as tropical hot and muggy, its significant thermal comfort attributes generality be locate in the late spring state of the ASHRAE gauges. As indicated by this issue and in light of the previous studies performed on the Malaysian guidelines, all the significant thermal necessities that must be taken into consideration and outlines and working stages have represented. The indoor conditions of an air-conditioned space for comfort shall be designed and maintained as follows:

i. Recommended temperature 24°C - 26°C.

ii. Recommended relative humidity 50% - 70%.

iii. Recommended air velocity 0.15 m/s – 0.5 m/s.