THERMAL COMFORT AND DUST CONCENTRATION LEVEL ANALYSIS OF AIR-CONDITIONED LECTURE ROOMS

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Final Report

Projek Sarjana Muda

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DECLARATION

I declare that this project report entitled "Thermal Comfort and Dust Concentration Level Analysis of Air-Conditioned Lecture Rooms" is the result of my own work except as cited in the references.

Signature : ………………………………

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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 the degree of Bachelor of Mechanical Engineering (Thermal Fluids).

Signature : ………………………………

Name : DR. TEE BOON TUAN

Date : ……………………………

ABSTRACT

The main purpose of this study is to evaluate the current thermal conditions and dust concentration level of selected air-conditioned lecture rooms. The selected lecture rooms were lecture room of BK10, BK12, BK13 and BK17. These lecture rooms are located at Technology Campus, University Teknikal Malaysia Melaka (UTeM), Faculty of Mechanical Engineering. The main physical parameters involved in this project are air temperature (Ta), relative humidity (RH), air velocity (Va) and particulate matter of 10µm and 2.5µm. The measurement is taken by using Thermal Micro Climate and Dust Trak II. The thermal comfort analysis of this study is conducted through DeltaLog10 software. These include the analysis of Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) index of measurements. A form of survey had been created and been separated to the occupant involved during the measurement for with occupant condition. According to the obtained results, almost 72% of air temperature measurement data is within the standard. Compared to relative humidity and air velocity, almost 67% of relative humidity and 86% air velocity readings were not satisfied the current standard. For the measurement of dust concentration, there were 100% readings of all particulate matter of 10µm measurement were satisfied the standard. On other hand, almost 90% of particulate matter readings of 2.5µm measurement were not satisfied the standard.

ABSTRAK

Tujuan utama kajian ini adalah untuk menilai keadaan terma semasa dan tahap kepekatan habuk bilik kuliah berhawa dingin yang dipilih. Bilik-bilik kuliah yang terpilih adalah bilik kuliah BK10, BK12, BK13 dan BK17. Bilik-bilik kuliah terletak di Kampus Teknologi Univeristi Teknikal Malaysia Melaka (UTeM), Fakulti Kejuruteraan Mekanikal. Parameter fizikal utama yang terlibat dalam projek ini adalah suhu udara (Ta), kelembapan relatif (RH), halaju udara (Va) dan bahan zarahan daripada 10μm dan 2.5μm. Ukuran ini diambil dengan menggunakan TermoMicro Climate dan Dust Trak II. Analisis keselesaan haba kajian ini dijalankan melalui perisian DeltaLog10. Ini termasuk analisis ramalan purata undian (PMV) dan indeks peratus ramalan ketidakpuashatian (PPD) ukuran. Satu bentuk kajian telah diwujudkan dengan mengambil kira kehadiran penghuni dan ketiadaan penghuni. Berdasarkan keputusan yang diperolehi, hampir 72% pengukuran suhu udara mengikut piawaian. Tetapi berbeza dengan kelembapan relatif dan halaju udara, hampir 67% daripada kelembapan dan 86% bacaan halaju udara tidak mengikut piawaian semasa. Untuk mengukur kepekatan habuk, terdapat 100% bacaan semua zarah pengukuran 10μm menepati piawaian. Disamping itu, hampir 90% daripada bacaan zarah pengukuran 2.5μm tidak menepati piawaian.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Malaysia is a tropical country that possesses a hot and humidity climate in every year. The average annual temperature in is in the range of 26-27^{o}C and the relative humidity (RH) of 70-90% (Yau, Chew, & Saifullah, 2011). In order to achieve comfort or good health to the occupants, the Air conditioning (AC) and ventilation systems are installed in the building and the temperature can be controlled. The improper control of relative humidity can cause the occupants to suffer from headaches, nausea, irritations of eyes, fatigue, rash and others, that is called Sick Building Syndrome (SBS). Indoor Air Quality (IAQ) is the important factor to produce the comfortable surroundings for the occupant's attention, concentration, learning, hearing and performance. When talking about indoor air quality, the main important factor is thermal comfort (Yau et al., 2011).

The improper thermal comfort will cause the negative impact on occupant's health and the improper functioning of sensitive electronic equipment like computers, or certain equipment in manufacturing process that had minimum and maximum temperature of operation (Bradshaw, 2006). Also the indoor air quality problems are basically due to the ventilation of the halls that is not functioned well. Occupants in the university spend 90% of their time in the campus for indoor activity. The pollutants in the halls surroundings can be 100 times greater of the outside pollutants (Yau et al., 2011). Lecture halls is usually overcrowded during the peak hours compare to during term break.

Thermal comfort is a parameter that determine the comfort zone or temperature range to ensure the occupants feel comfortable. In order to determine the comfort zone of the occupants, the measurement of the current thermal comfort level should be compare with the relevant standards. ASHRAE Standard 55 is a standard that defines the thermal comfort according to the surrounding situation. Usually the common parameters to be measured for the thermal comfort are air temperature, average radiant temperature, relative humidity and air speed and the personal factor like indoor activity and clothing.(Nasir et al., 2011)

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). The pollutants whether primary or secondary are definitely divided into two classifications according to the chemical composition of organic and non-organic. Organic materials contain of carbon, oxygen, hydrogen, nitrogen, phosphorus and sulphur. There are only carbon and oxygen in organic substances like hydrocarbons. For the organic material, the component involved in these materials of contaminated air are carboxylic acids, alcohols, esters and other organic sulphur. In- organic material found in the contaminated air is carbon monoxide (CO), carbon dioxide (CO2), carbonates, sulphur oxides (SOx), nitrogen oxides (NOx), ozone (O3), hydrogen fluoride (HF) and hydrogen chloride (HCC)(Nasir et al., 2011).

1.2 PROBLEM STATEMENT

Mechanical Engineering Faculty building is a one of the faculty's building in University Teknikal Malaysia Melaka. It is located at UTeM Technology Campus. It is surrounding with industrial factory like Konica Minolta, Allan D'lious Marketing and one of building construction behind the Mars building. The building contains lecture room, lecturer room, library, lab, café and others. The common factor that affected the air indoor quality is commercial or manufacturing like dry cleaning, restaurant, photo-processing, automotive shop, gas station, paint shop, electronics manufacture and various industrial operations. When it surrounding with industrial factory, it means that it will be disturb the air environment of the building (US EPA, n.d.). The occupants are always experiencing the uncomfortable thermal environment that disturbed the occupant's performance like attention, focus, learning, hearing and seeing in their lecture room. The high occupant's density and the negative influence which is unsatisfactory thermal environment is disturbed the thermal comfort of the lecture rooms. It is suspected that the air conditioning of the lecture room is not functioning at optimum level. The occupants also always experiencing the Sick Building Syndrome (SBS) like headache, irritation of eyes and fatigue during their lecture slot. The factor of this SBS is suspected coming from the high dust concentration in the class.

Figure 1.1 Mars building in Technology Campus, UTeM.

1.3 OBJECTIVE

The objectives of this project are as follows:

1. To evaluate the current thermal conditions of air-conditioned lecture rooms
2. To compare measured physical conditions to the comfort zone specifications by the existing standard.
3. To investigate whether the current thermal conditions and dust concentration level may have significant effects on occupants' health in the selected lecture rooms.

1.4 SCOPES OF PROJECT

The scopes of this project are:

1. The report in only present the analysis of the thermal comfort and dust concentration measurement. The measurement of analysis will be measured using the equipment obtained at thermal lab.
2. The analysis is focus on the lecture room of BK4, BK9 and BK11 With occupants and without occupants.
3. The result is compared to ASHRAE-55, MS1525 and Malaysian Air Quality Guideline standard and several suggestions is proposed.

CHAPTER 2

LITERATURE REVIEW

2.0 BACKGROUND

2.1 THERMAL COMFORT

The definition of thermal comfort defined by ASHRAE Standard 55-1992 is a state of mind that satisfied with terms of environment. There are several factors of thermal comfort which are air temperature, average radiant temperature, relative humidity and air speed and the side factor obtained activity and clothing. Several factors that involving to rise the temperature in a building are emission of heat from the lights and electrical appliances, the admission of heat from outside to the walls, windows and roofs of building and heat convection of hot air from outside the building. The standard thermal comfort in Malaysia when the relative humidity (RH) between 45% - 80.6% and the temperature is between 25.5^{o}C – 28.5^{o}C in dry bulb temperature. (Nasir et al., 2011)

There are several parameters involved in thermal comfort such as temperature, humidity, air motion and side factor like dress and occupant's activity level. To maintained the thermal comfort, human metabolism and the equipment that generate heat should be dissipate. Then the thermal equilibrium will maintain with the surroundings. ASHRAE Standard 55 (2004) stated that operating temperature and humidity is accepted in summer when the temperature is in the range of 24^{o}C-28^{o}C with 30% relative humidity and 23^{o}C - 25.5^{o}C with 60% relative humidity and air speed of below that 0.25 m/s for 0.5 clo light clothing.

The value of humidity below 50% is contribute to the spreading of influenza virus and will cause tissue weakness. The discomfort situation will happen by drying out the mucous membrane and can cause skin rashes. Office worker will feel comfort when the relative humidity is at 50%. The massive humidity will affect the office feel stuffy. Then bacterial and fungal can growth easily in sealed buildings (Yau et al., 2011).

2.1.1 Air Velocity

Air velocity also called as air movement. Air velocity is much related to heat lost by human body. If the rate of the air velocity is at low level, the heat loss produced by human body by evaporation will be rise. This is because the ability of air to absorb the moisture is much related to evaporation process. The air moisture will be change with a lower moisture content when the air passed through over the body and it will absorb the moisture from skin. The quantity of moisture will be lower if the rate of air velocity is at lower value (Bradshaw, 2006).

If the air velocity is at static condition, the air nearest the skin will absorb the moisture only until it is saturated. If the saturation point is reached the heat lost by evaporation will be decrease. The heat lost through convection is also effected by air velocity. The constant warm air next to the skin is being replaced with cooler air that will suck more heat. The air velocity also able to increase the amount of heat lost by radiation as it removes heat from the surrounding (Bradshaw, 2006).

2.1.2 Relative Humidity

The determination of moisture content in air and the value of the ability of moisture to be absorbed by air is called relative humidity. To determine the quantity of air conditioning needed in the building, the relative humidity of indoor is as the indicator. It has a tremendous effect on the amount of heat rejected through the radiation process by the body. The relative humidity can be determined by dividing the value of water vapour that contained in air by the quantity of the air could hold when saturated at the same temperature. Human body will reject more heat through evaporation process when the relative humidity of air surroundings at low level. Also, the human body will reject less heat through evaporation process when the relative humidity of air surroundings at high level. Generally, almost person will satisfy the comfortable when air is at condition of 26.7^{o}C temperature and 50% relative humidity (Bradshaw, 2006).

2.1.3 Radiant Temperature

The warm object that transfer heat and radiates are called thermal radiation. According to the Handbook of Air Conditioning and Refrigeration second edition, mean radiant temperature can be defined as the temperature of a uniform black enclosure in which an occupant would have the same amount of radiative heat exchange as in an actual indoor environment. The radiation normally come from the sunlight, light bulb and others specially for building. The sense of radiant temperature by human usually stronger than air temperature. This is because the human skin has massive emissivity and absorptive. Therefore, the skin is very sensitive to the radiant heat loss and gain (Bradshaw, 2006).

The mean radiant temperature can be measure by using globe thermometer or also called as globe temperature. This equipment contains of a 152 mm copper hollow sphere diameter. It is coated with black paint on the outer space. Inside the globe there was a component called thermometer or thermocouple with the sensing bulb or the thermo junction located at the middle of the sphere (Bradshaw, 2006).

2.2 PREDICTED MEAN VOTE (PMV) AND PREDICTED PERCENTAGE OF DISSATISFIED

Predicted mean vote (PMV) is the thermal index value corresponding with a mean vote of neutral on the thermal sensation scale according to ASHRAE Standard. The predicted percentage of dissatisfied (PPD) an index establishes a quantitative prediction of the percentage of thermally dissatisfied people determined from PMV.

The PMV model uses heat balance principles to relate the six key factors for thermal comfort parameters listed. The PPD is related to the PMV and based on the assumption that people voting +2, +3, -2, -3 on the thermal sensation scale are dissatisfied and on simplification that PPD is symmetric around a neutral PMV. According to ASHRAE Standard, they recommended the PPD below 10 and the PMV in the range of -0.5 to +0.5.

2.3 METABOLIC RATE

Basically the metabolic rate is depending on the activity level of human and proportional to weight. Body surface area, health, sex, age, clothing, the thermal of surrounding and atmospheric pressure is related to the metabolic rate. The maximum production of metabolism is at the age's range of 10 years and minimum at old age. It can be higher when fever, continuous activity or cold environmental conditions happen.

The heat production by human body increases proportional to exercise's level. It is important to ensure the metabolic rate of human physical activities in other to ascertain the comfort and health of optimum environmental conditions. The metabolic rate can be analysed from sleeping to high level of work as shown the Table 2.1 below (Bradshaw, 2006)

Table 2.1 The Activities Metabolic Rate from ASHRAE 1989

Activity	Metabolic Rate in Met Units	Activity	Metabolic Rate in Met Units
Resting		Miscellaneous Work	
Sleeping	0.7	Watch-repairing, seated	1.1
Reclining	0.8	Lifting/packing	1.2 to 2.4
Seated, reading	0.9	Garage work	2.2 to 3.0
Office Work		Vehicle Driving	
Seated, writing	1.0	Car	1.5
Seated, typing or talking	1.2 to 1.4	Motorcycle	2.0
Seated, filling	1.2	Heavy vehicle	3.2
Standing, talking	1.2	Aircraft flying, routine	1.4
Drafting	1.1 to 1.3	Instrument landing	1.8
Miscellaneous office work	1.1 to 1.3	Combat flying	2.4
Standing, filling	1.4		
Walking (on level ground)		Leisure Activities	
2 mph (0.89 m/s)	2.0	Stream Activities	1.2 to 2.0
3 mph (2.34 m/s)	2.6	Golf, swinging and walking	1.4 to 2.6
4 mph (1.79 m/s)	3.8	Golf, swinging and with golf cart	1.4 to 1.8
Domestic Work		Dancing	2.4 to 4.4
Shopping	1.4 to 1.8	Calisthenics exercise	3.0 to 4.0
Cooking	1.6 to 2.0	Tennis, singles	3.6 to 4.6
House cleaning	2.0 to 3.4	Squash, singles	5.0 to 7.2
Washing by hand and iron	2.0 to 3.6	Basketball, half court	5.0 to 7.6
Carpentry		Wrestling, competitive or intensive	7.0 to 8.7
Machine sawing, table	1.8 to 2.2		
Sawing by hand	4.0 to 4.8		
Planing by hand	5.6 to 6.4		