INVESTIGATION OF AIR FLOW IN CHAMBER USING AIR-CONDITIONING UNIT FOR THERMAL COMFORT

TEO YIN YIN

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Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

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DECLARATION

"I hereby, declare this thesis is result of my own research except as cited in the references"

Signature : ………………………….
Author Name : Teo Yin Yin
Date : ………………………….

DEDICATION

To

My Beloved Family

Jenny

Sonia

Ivan

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ABSTRACT

Control of relative humidity is an essential aspect of maintaining indoor air quality in an air-conditioned. The aim of using air-conditioning is to provide thermal comfort and control the quality of air. Humans feel comfort when air temperature is between 22^0C to 27^0C with the relative humidity of 40% to 60% when the air speed is about 0.25 m/s. This project focuses on both temperature and humidity control of air in order to achieve thermal comfort zone. The experiments were based on the acceptable thermal comfort conditions in a chamber by referring to the ASHRAE standard and the thermal comfort standard from Building Regulations of Singapore. Experiments were conducted using Air-Conditioning Unit. Several parameters has considered in this study are air velocity, Pre-heater, and damper. The results reveal that the suitable setting is achieved at 2.75 m/s air velocity with 100% fresh air intake at the condition of operates a Pre-heater. In addition to the above work, Computational Fluid Dynamics with using ANSYS CFX software is used to investigate the air flow pattern and the temperature distribution in chamber. Simulation results is validated the experimental data.

ABSTRAK

Mengawal kelembapan relatif adalah satu aspek penting memelihara kualiti udara dalam sebuah tempat yang berhawa dingin. Tujuan penggunaan sistem penyaman udara adalah untuk keselesaan terma dan mengawal kualiti udara. Manusia berasa selesa pada suhu antara 22^0C hingga 27^0C dengan kelembapan relative antara 40% dan 60% dengan kelajuan udara adalah lebih kurang 0.25 m/s. Objectif projek ini adalah mengawal suhu udara dan kelembapan udara supaya mencapai zon selesa. Eksperimen adalah diasaskan keselesaan terma yang boleh diterima syarat-syarat di dalam sebuah bilik dengan merujuk kepada tahap ASHRAE dan tahap keselesaan terma daripada Peraturan Bangunan Singapura. Eksperimen-eksperimen telah dijalankan dengan menggunakan Unit Penyaman Udara. Beberapa parameter dalam kajian ini adalah halaju udara, Pra-pemanas, dan peredam. Keputusan menunjukkan parameter yang sesuai adalah dicapai pada 2.75m/s halaju udara dan 100% udara luar dengan satu Pra-pemanas dihidupkan. Kaedah *Computational fluid Dynamic* dengan perisian ANSYS CFX digunakan untuk simulasi corak aliran udara dan taburan suhu dalam kebuk. Hasil simulasi telah disahkan oleh hasil eksperimen.

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Cp	=	Specific heat capacity
m_w	=	Mass of water vapor (kg, lb)
m_a	=	Mass of dry air (kg, lb)
$p_{(H_2O)}$	=	Partial pressure of water vapour in the mixture
$p^*_{(H_2O)}$	=	The saturated vapour pressure of water at the temperature of the mixture.
RH	=	Relative humidity of the mixture being considered
t_1	=	Dry-bulb temperature of air at fan inlet
t_2	=	Wet-bulb temperature of air at fan inlet
t_3	=	Dry-bulb temperature of air after leaving Pre-heater
t_4	=	Wet-bulb temperature of air after leaving Pre-heater
t_5	=	Dry-bulb temperature of air after cooling
t_6	=	Wet-bulb temperature of air after cooling
t_7	=	Dry-bulb temperature of air after Re-heating
t_8	=	Wet-bulb temperature of air after Re-heating
x	=	Humidity ratio ($kg_{water}/kg_{air,}$ lbwater/lbdry_air)

LIST OF ABBREVIATIONS

3D	=	Three Dimensional
ASHRAE	=	American Society of Heating, Refrigeration and Air conditioning Engineers
CAD	=	Computer-Aided Design
CFD	=	Computational Fluid Dynamics
HVAC	=	Heating, Ventilation and Air-conditioning
IAQ	=	Indoor Air Quality

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CHAPTER 1

INTRODUCTION

1.1 Background Study

The variation in temperature, humidity, and wind occurring throughout the world provides the climates which vary with season of the year and with geographical locations. Hence, in very few places the natural environment is comfortable for human beings or suitable for a specific product or process throughout the year. Since the principal purpose of air-conditioning systems is to provide conditions for humans to stay with thermal comfort, air conditioning that based on the climatic considerations been suggested to provide conditions for human thermal comfort.

According to the comfort standard from Building Regulation Singapore, a space air-conditioned temperature had specified between 23 and 27 ^{0}C, relative humidity not exceeding 75% and maximum air movement (relative velocity) of 1.25 m/s. The air motion also plays an important role to determine the human comfort. It removes the warm, moisture air that builds up around body and replaces it with fresh air. Air speed of about 0.25m/s will make people feel comfortable. Beside human thermal comfort, air conditioning is also widely used for the efficiency and effectiveness of manufacturing process, or to maintain the quality and life of a stored product.

Air-conditioning not just as simple the cooling of air, furthermore it includes some processes in some way to improve the quality of air. More formally, air-conditioning maybe defined as a form of air treatment which controls simultaneously the temperature, humidity, cleanliness and distribution of air to meet the requirements of the conditioned space. To provide these functions with most natural atmospheres, heating, cooling and regulation of thermal radiation was required for temperature control. Humidification and dehumidification was required for humidity control and introduction of outside ventilation air.

The air flow rate was affect the air flow pattern and humidity inside a room to achieve thermal comfort. Data on the effect of air motion and temperature to the humidity of the air in the chamber was go for determine the system thermal comfort.

1.2 Problem Statement

In fact of hostile environment, the design specification for a comfort conditioning system is intended to be the framework for providing a comfortable environment for human being throughout the year. The comfort zones are intended to provide acceptable thermal environment for occupants wearing typical indoor clothing and at a near sedentary activity. To be comfortable, people require a certain amount of ambient humidity that not too high, and not too low.

Poor air quality in homes can cause asthma in children, and that poor air quality in workplaces decreases productivity. One of the basic requirements creating a comfortable environment is to maintain thermal conditions comfortable for occupants as these have a direct effect on their health, productivity and morale. Low humidities, with dew points less than 2^0C, tend to give a dry nose and throat, and eye irritation. A dusty environment can exacerbate low humidity skin conditions. High humidities support the growth of pathogenic and allergenic organisms, certain fungi, mycotoxins and house mites. Factors that influence thermal comfort are air temperature (dry-bulb), relative humidity, air velocity, radiation (mean radiant temperature), metabolic rate, and clothing insulation.

An investigation was done for this project to control the level of air temperature and humidity in a chamber using Air-Conditioning Unit. Humidification and dehumidification were control by varying the amount of moisture and quantity of return air with other fix experimental setting. The corresponding range of experimental setting that give relative humidity lie on the comfort zone was determined through the psychrometric chart. For CFD (Computational Fluid Dynamics) simulation, the ANSYS CFX software is used to simulate the air flow pattern in a chamber. Simulation of temperature distribution was done by using ANSYS CFX software. Experimental results was use to validate the simulation result.

1.3 Objectives

The objectives of this project are to study the comfort zone of air characteristic and investigate the characteristic of the air flow in chamber. The simulation result was validated with experimental data.

1.4 Scope

The investigation was based on study the comfort zone of air characteristic using Air-Conditioning Unit. A simulation system was used from the condition of real air conditioning system in a chamber. CFD simulation was used to simulate the temperature profile of air in chamber. Experiment was set-up based on the control of water heater and quantity of return air to get the suitable relative humidity in chamber. Relative humidity which achieved thermal comfort was determined by using the psychrometric chart. Furthermore, the wet-bulb and dry-bulb temperature at the inlet and outlet of chamber was obtained. Analysis was done based on the air-conditioning testing results to get the suitable settings which give comfort condition. The air flow in a chamber was examined and simulate by using CFD simulation.

CHAPTER 2

LITERATURE REVIEW

2.1 Background of Air-conditioning System due to Thermal Comfort

Air-conditioning systems is used in many parts of the world. The purpose of most systems is to provide thermal comfort and an acceptable indoor air quality (IAQ) for occupants. With the improvement of standard of living, occupants require more and more comfortable and healthful indoor environment. People spend 80 to 90% of their time in indoors, and indoor environment has important effects on human health and work efficiency. A comfortable and healthy indoor air environment is favourable to occupants. In recent years, indoor thermal comfort has been improved greatly due to the development of air-conditioning systems. However, health problems related to poor IAQ appear more frequently, and it is the indoor pollutants that lead to poor IAQ. Control of relative humidity is an essential aspect of maintaining indoor air quality in an air-conditioned space.

Thermal-comfort is attained when a thermal balance is achieved in which no heat storage occurs in the body. Although this can be achieved over a wide range of thermal-environment conditions, thermal-comfort is associated with conditions to which the body can readily adjust. It is defined as ‘‘that state of mind which expresses satisfaction with the thermal environment’’. The thermal-environment parameters involved are all those affecting body heat gains and losses. Air temperature, air humidity, air velocity, mean radiant temperature as well as human clothing and activity levels are factors that determine the heat balance of a human body in a given thermal environment. Several models are available in literature to relate the human sensation of comfort to those factors. In one basic form, the human body has been considered as an inert object exchanging energy with its environment through radiation, convection and conduction and capable of losing heat by evaporation and adapting to conditions through the body regulatory system. Prediction of thermal-comfort has been of substantial interest to ASHRAE (American Society of Heating Refrigeration and Air-conditioning Engineers), which developed the original comfort index based on effective temperature.

The sensations of warmth or cold experienced by human body depend not only on the dry-bulb temperature but also on the moisture content of the air. Cooling applications remove only the sensible heat fall short of establishing comfortable conditions if the latent heat gain is particularly high. The air will be cooler under these conditions, but it will feel damp and uncomfortable. In order to meet minimal standards of comfort, both sensible and latent heat must be reduced to and acceptable level.

2.2 Studies on Air Flow Pattern and Thermal Comfort on Air-conditioning Unit

Thermal comfort encompasses environmental parameters such as air-temperature, radiation, humidity and air-movement and personal parameters such as clothing and activity. The combined influence of all the parameters was quantified with the introduction of the 'comfort equation', subsequently resulting in the presentation of ASHRAE thermal comfort standards as performance criteria for buildings.

Human beings want to live in comfort environment that neither hot nor cold, neither humid nor dry. The comfort of the human body depends primarily on three of the main factors which are dry-bulb temperature, relative humidity, and air motion. Most people feel comfortable when the environment temperature is between 22^0C and 27^0C with relative humidity of 40% to 60% at air speed about 0.25m/s.

From the study by S.C. Sekhar (1995), acceptability of such space conditions from thermal comfort considerations has been discussed with reference to comfort diagrams and it has been shown that higher space temperatures of about 26 °C with relative humidity levels around 60% are quite acceptable from thermal comfort considerations in the tropics. The ASHRAE upper limit on relative humidity is 60% and the average summer air movement should not exceed 0.25 m/s. In tropical buildings, it is not common to find low space temperature around 23^0C and high relative humidity levels in order of about 70 to 75%. Building in the Asian rim countries typically does not employ humidity control as part of the air-conditioning system. According to Building Regulation of Singapore specify a space air-conditioned temperature between 23 and 27^0C, relative humidity not exceeding 75% and maximum air movement (relative velocity) of 1.25m/s.

J. W. Wan, Kunli Yang, W.J. Zhang and J. L. Zhang (2008) had investigated a new method of determination of indoor temperature and relative humidity with consideration of human thermal comfort. From the viewpoint of indoor thermal environment design, effective temperature represents the human thermal comfort level. It should be noted that surely there are many other factors that influence human thermal comfort, notably air velocity. However, as far as air velocity, its effect may be replaced by humidity. It is common sense that for a given human thermal comfort level, increase in indoor temperature needs to be accompanied with decrease in indoor humidity. It seems to be such that indoor temperature and indoor relative humidity are two major important parameters to be chosen. Their sensitivity analysis of the six comfort factors showed that the clothing worn by occupants, the activity level, air temperature, and mean radiant temperature all have significant effects on human thermal comfort. Humidity and air velocity play rather small roles in comparison, but they seem to regulate the sensitivity of the other four factors and are therefore important. Humans are more sensitive to variations in temperature than those of relative humidity.