UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EVALUATION OF DECENTRALISED FANS EFFECTIVENESS IN OFFICE BUILDING VENTILATION SYSTEM

This report submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree of Engineering Technology (Bachelor of Mechanical Engineering Technology in Refrigeration and Air-Conditioning Systems) with Honours

By

SEM EPOI LAENG
B071410471
950703-13-6123

FACULTY OF ENGINEERING TECHNOLOGY

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DECLARATION

I hereby, declared this report entitled “Evaluation of Decentralised Fans Effectiveness in Office Building Ventilation System” is the results of my own research except as cited in references.

Signature : .....

Auther’s Name : Sem Epoi Laeng

Date : .....

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Refrigeration and Air-Conditioning Systems) with Honours. The member of the supervisory is as follow:

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(Madam Noor Saffreena Binti Hamdan)

ABSTRAK

Sistem HVAC mempunyai pengaruh yang signifikan terhadap penggunaan tenaga bangunan. Mengurangkan penggunaan tenaga yang digunakan oleh bangunan menjadi kepekaan kepada semua orang pada masa ini. Oleh itu, pembangunan sistem pengudaraan mekanikal dengan permintaan tenaga yang rendah diperlukan. Dalam sistem saliran konvensional, terdapat tekanan statik yang positif berbanding dengan tekanan di dalam bangunan. Menggunakan peredam dalam sistem pengudaraan telah menyebabkan aliran udara dan tekanan udara diterbalikkan dalam sistem penyaluran. Oleh itu, kipas memerlukan lebih banyak kuasa bagi kipas untuk menyediakan aliran udara yang mencukupi untuk membekalkan ke dalam bilik untuk keselesaan termal yang diinginkan. Penggunaan tenaga yang tinggi jelas oleh sistem ini. Tujuan kajian ini adalah untuk menentukan potensi penjimatan tenaga dalam sistem HVAC dengan penilaian eksperimen ke sistem pengudaraan. Kajian ini menilai keberkesanan kipas desentralisasi ke sistem pengudaraan bangunan pejabat. Projek ini dilakukan dengan membangun kit jurulatih sistem salur untuk mengkaji kelajuan udara dan pengedaran suhu. Kipas yang terdesentralkan dan peredam digunakan untuk membandingkan bagaimana ia mempengaruhi halaju udara dan suhu dalam sistem salur. Dalam projek ini, sistem dengan kipas yang terdesentralisasi mempunyai pengedaran suhu yang baik dan halaju udara yang tinggi di dalam bilik berbanding sistem dengan peredam. Penurunan suhu paling tinggi dalam pendapatan kajian ialah semasa sistem digunakan dengan kipas tidak terdesentralisasi pada kipas utama di kelajuan maksima iaitu 26.5 C° manakala halaju udara telah menaik lebih dari 25 % dalam kesemua empat bilik. Menggunakan kipas terdesentralisasi, penyejukan adalah pesat dan kecekapan tenaga lebih tinggi berbanding dengan sistem yang menggunakan peredam. Dalam hasil kajian, penggunaan tenaga telah dikurangkan sebanyak lebih dari 10 %.

ABSTRACT

The HVAC system have a significant influence on the energy consumption of a buildings. Reducing the energy demand used by the building is everyone concern nowadays. Therefore, development of a mechanical ventilation system with a low energy demand are required. In the conventional ducting system, there is a positive static pressure compared with the pressure inside the building. Using damper in the ventilation system had cause reversed air flow and pressure drop in the ducting system. Therefore, the fan need more power for fan to provide enough air flow to be supply into the room to achieve desired thermal comfort. This clearly energy usage is high by the system. The purpose of this study is to determine the energy saving potential in the HVAC system by experiment evaluation to the ventilation system. This study evaluates the decentralised fan effectiveness to the office building ventilation system. This project is done by developing a ducting trainer kit to study the face velocity and temperature distribution. The decentralised fan and damper are used to compare how they affect the air velocity and duration for temperature distribution in a room. In this project, the system with decentralised fan have good temperature distribution and high air velocity in the room compare to the system with damper. The highest temperature drop in the experiment result is when the system is with decentralised fan at main fan maximum speed, that is 26.5 C° while the face velocity in the room had increased more than 25 % in the four room. Using decentralised fan, the cooling is rapid and the energy efficiency is higher compared with the system that using damper. In the experiment finding, the energy consumption can be reduced more than 10 %.

DEDICATION

Special dedication to my beloved parent for their unconditional support with my studies especially during the progress of this project. I also dedicate this dissertation to my special friends, especially my supportive classmates of BETH KOHORT 4 for helping me through the process of completing this thesis. A special thanks to my supervisor Madam Noor Saffreena Binti Hamdan who always guides and help me to complete this project. Thank you for everything.

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List of Abbreviations, Symbols and Nomenclatures

ADS	-	Air distribution system
AHU	-	Air Handler Unit
AMCA	-	Air Movement and Control Association
ASHRAE	-	American Society of Heating, Refrigeration and Air-Conditioning Engineer
BDP	-	Bachelor Degree Project
HVAC	-	Heating Ventilation and Air Conditioning
IAQ	-	Indoor Air Quality
IECC	-	International Energy Conservation Code
In.Wg	-	inches of water gauge
RM	-	Ringgit Malaysia
WMC	-	Wonder Metal Corporation

CHAPTER 1

INTRODUCTION

1.0 Introduction

In this chapter, introducing the Bachelor Degree Project (BDP) that include the background, problem statement, objectives, scopes of research and report organization of the project.

1.1 Background

Due to global climax change, the air conditioning system become a compulsory for every building to achieve thermal comforts and good indoor air quality. According to Sabri M., Ahmad S., Bahadur H., & Hagishima A. (2016), occupant's satisfaction is an important part to measure a building performance.

There are many types of air conditioning system used in a building such as air-cooled chiller and water-cooled chiller is the commonly systems installed in a building. One of the major component of an air conditioning system in a building is the ducts. Ducting is a system that give passages to the air flow used in Heating Ventilation and Air Conditioning (HVAC) system to deliver and removed air in a control space. Ducting are commonly used to deliver ventilated air to the control space to obtain a desired indoor air quality and thermal comfort.

A ducting system is a centralised system with a blower at the Air Handler Unit (AHU) to distribute air into the space area. The air flow and pressure in the ducting system are varies with ducting design and blower types (Stephens B. 2014). Bigger ducting size have a high pressure drop and air velocity is low. The blower speed is depending on the blower types and models. The used of damper

in ducting of the conventional centralised system affect the air velocity and pressure. High pressure drop and reversed airflow occur in the ducting system. Thus, the fan in the AHU required large power to provide enough air flow rate to cool the control space.

This thesis report is about evaluation of decentralised fan effectiveness in office building ventilation system. The parameter that measured are face velocity, temperature distribution power consumption. A solution to meet green building concept that is low energy consumption are suggested at the end of the project regarding the data collected.

1.3 The Purpose of The Research

The purpose of this project is to evaluate the decentralised fan effectiveness to the ventilation system in office building. The study of air velocity, temperature distribution and power consumption in a ducting are required to build and develop a better HVAC system. Thus, this work will investigate the effectiveness of the decentralised fan to the air velocity and temperature distribution in ducting system.

The investigation is conducted using dual branch duct trainer kit that have two room for each branch. By the end of this project, the effect of decentralised fan and damper to the face velocity and temperature distribution in ducting system will be determine. The effectiveness of energy also analysed.

1.4 Problem Statement

There are challenges being faced by the Heating, Ventilation, Air-Conditioning (HVAC) industries such as energy consumption, environment issue and life cycle cost of the system installed. One of the major challenges that everyone concern now are the energy consumption by the HVAC system.

The air conditioning system represent a huge number of the total energy consumption in a building (Sarbu I., & Adam M., 2014). Finding the best method to reduce energy consumption in building without compromising comfort and Indoor Air Quality (IAQ) in the building is a target. It is essential to develop

ventilation systems with low energy consumption to reduce the total cost of any building nowadays.

Traditionally the damper had been used to control the air flow to the desired ventilated area in the ducting system. However, the used of damper had cause high pressure drop in the ducts which lead to high demand on power usage by the fan to supply enough air so that the desired air flow are achieved. One of a potential for energy saving in HVAC system is by reducing the energy consumption by the fan for the air transport in the system (Gunner, Hultmark, Vorre, Afshari, & Bergsøe, 2014).

Damper is a valve or plate that stop or regulates the air flow of air inside a duct. A damper will increase the air velocity in the ducting. However, it cause reversed air flow in the duct that cause high pressure drop (Gunner, Afshari, & Bergsøe, 2015). Thus, clearly high energy required by the AHU fan to operate whereas nowadays energy saving is on demand. A method to avoid reversed air flow to occur in the duct are made by making investigation using decentralised fan so that the AHU fan does not need high energy during operated to achieve the desired thermal comfort and good IAQ. The decentralised fan will increase the air velocity. A high air velocity can increase the rate of heat transfer. Thus, the rate of temperature distribution will increased.

1.5 Objectives

Based on the research tittle “Evaluation of Decentralised Fans Effectiveness in Office Building Ventilation System” the objectives of this project are as followed:

a) To design ducting trainer kit.
b) To analyse face velocity and temperature distribution period of decentralised fan and damper in ducting system.
c) To compare energy efficiency between decentralised fan and damper.

1.6 Scope of The Research

This section explains about the scope of work for this project. In order to achieve the project objectives, a ducting trainer kit is built. This study focuses on decentralised fan effectiveness to the ducting system. The important parameter involved are the power consumption, face velocity and temperature distribution in the ducting system.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In this chapter, there are briefings about the topic study from a few of journal on the web, paper and research, and some other resources like HVAC books that have relation to the topic studies.

2.1 Heating, Ventilation, and Air-Conditioning (HVAC) System

HVAC system had become major part of the building today due to the demand on good ventilation of air. HVAC system had developed dramatically in this recent years related to the living standard of the people and the outdoor environment changed. The HVAC system represent a big number in the building sector (Perez-Lombard, Ortiz, & Maestre, 2011). The main purpose of HVAC system is to provide conditions air for human thermal comfort and suitable indoor air quality in the occupied space of the building. Human thermal comfort is a feeling of human body when tends to accept the thermal of surroundings. As defined by American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) it is the state of mind that expresses satisfaction with the surrounding (ASHRAE Standard 55).

In any building today have an air conditioning system. According to Shan K. Wang (Shan K. Wang. (2001). Handbook of Air Conditioning and Refrigeration. United States of America: McGraw-Hill.) Air-conditioning system

is a composed of components and equipment arranged in sequence to condition the air, to transport it to the conditioned spaced and to control the indoor environmental parameters of a specific space within required limits. Air conditioning system provided occupants a comfortable and healthy indoor environment to do their daily routine. In this modern day, air conditioning is used in domestic and commercial environments.

2.2 Ventilation System

Another important characteristic in a HVAC system is the ventilation system. Ventilation is the process of supplying "fresh" air from the outside to the building in the proper amount to avoid contaminants growth (Samuel C. Sugarman (2005). HVAC Fundamentals. United States of America: The Fairmont Press).

The purpose of ventilation is to change air conditioned in any space to provide better indoor quality. It helps maintaining a healthy environment by regulating moisture and humidity, controlling temperatures and removing contaminants. It is the most important factors to maintain the good indoor air quality in a building. There are three types of air ventilation that is natural ventilation, force or mechanical ventilation and hybrid ventilation.

2.2.1 Natural Ventilation

Natural ventilation is supplying and removing air through indoor space by natural means. There are no fan or mechanical system used for the ventilation to occur. It is occurred because of the outdoor air flow caused by the difference pressure between building and surrounding to provide ventilation. Natural ventilation can simply occur by opening the window.

2.2.2 Forced Ventilation

Mechanical ventilation is driven fan or any other mechanical plant such as a HVAC system application. The ventilation occurs by external mean that forced the air to achieved desired ventilation. The conversation of energy is happened. The mechanical plant used electricity to produce pressure to allow air to flow.

2.2.3 Hybrid Ventilation

Hybrid ventilation is the combines of natural and typical mechanical. It purpose is to reduce to HVAC energy demand based on the outdoor thermal condition (Kim & Baldini, 2016).

2.3 Air Distribution System (ADS)

Air Distribution System (ADS) is an important component in a HVAC system. ADS is a proper method to deliver air to the space of the building. It provides a circulated ventilated air to the space building. Air distribution system (ADS) deliver the conditioned forced air made by an external device such as a blower to carry heat and circulate it in building space to achieve required of thermal comfort.

According to Samuel C. Sugarman, air moves through the duct due to difference in pressure (Samuel C. Sugarman (2005). HVAC Fundamentals. United States of America: The Fairmont Press). In a HVAC system the air are moves from higher pressure to a lower pressure in the ducts by fan. The amount of air distributed to the room in a building should be in the right amount to meet occupant thermal comfort and avoid contaminant growth. A successful air distribution can be measured by its thermal comfort performance and its energy efficiency.

2.4 Fan in HVAC system

The fan is the most important part of any ventilation system because a fan is the prime mover of air in the HVAC system. It provides continuous circulation of air throughout the system and conditioned the spaces area. AHU is the complete unit where the fan can be found. The fan converts the rotational mechanical energy to a total pressure increase of a moving air (Thomas E. Mull. (1998). HVAC Principles and Applications Manual. New York: Mc Graw-Hill). The total pressure consists of static pressure and velocity pressure. Selecting the appropriate fan is needed accurate calculation of static and velocity pressure in the duct work. There are many types of fan used in HVAC system. The types of fan used are depends on the application or requirement characteristic.

2.4.1 Fan Types

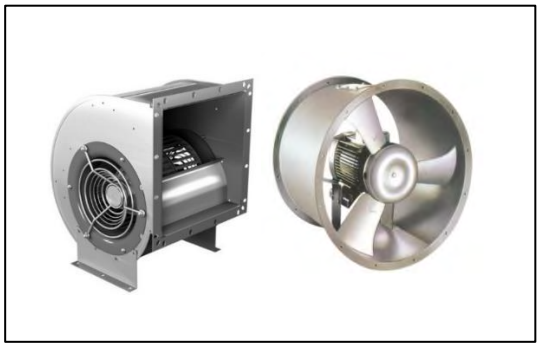

Figure 2.1: Centrifugal Fan and Axial Fan

The common types of fan used for HVAC systems are axial and centrifugal fan. Table 2.1 below shown centrifugal and axial fan that can be found in a HVAC system. An axial fan used a propeller to draw the air into the fan and blow it in the same direction. The air flow within the fan wheel parallel to the fan shaft. The common type of axial flow fan is propeller, tube axial flow and vane flow fans. Centrifugal fan draws the air into the inlet of the blower housing and discharges the air 90 degrees out of the housing inlet. The working principle of this fan is the air are radially

discharged from the impeller. Centrifugal fan types are forward curved, backward inclined, backward curved and air foil fans. These two types of fan increase the total pressure of the air by producing the velocity pressure.

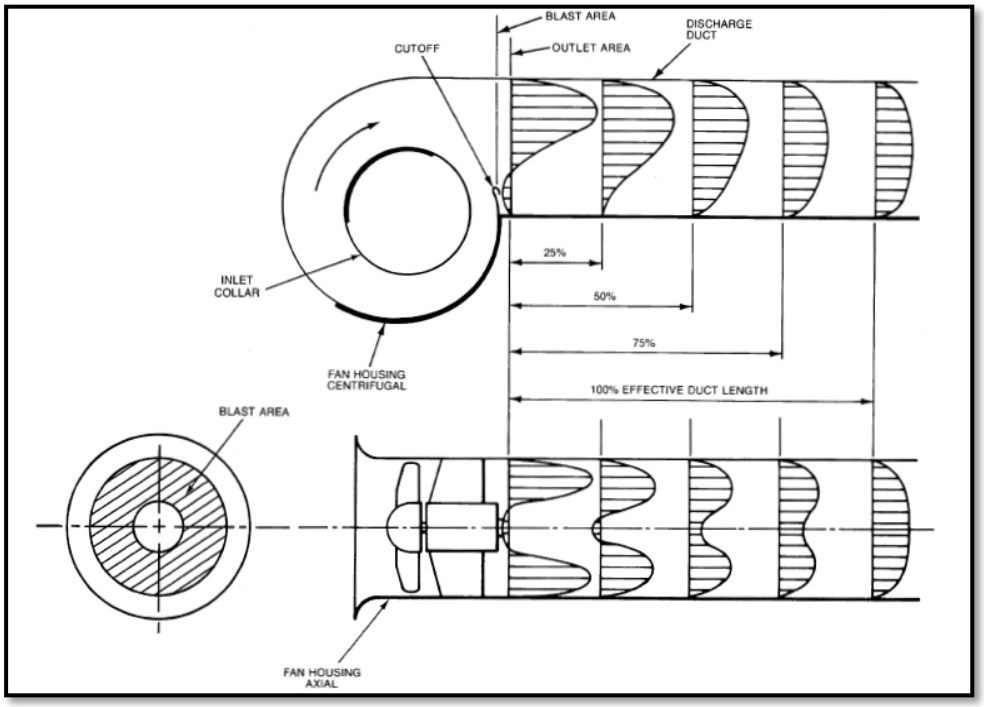

Figure 2.2: Velocity Profile in Straight Fan Outlet Duct

(Source: Coefficients, F. L. (2003). Duct design. *Analysis*.)

2.4.2 Fan Law

Fan law is the rules to express the relationship between variables involved in fan performance. The purpose of fan law is to use to predict the fan performance in a given system. Fan law are applying both to centrifugal and axial flows. The requirement need is the ratios of the fluid force are the same. Having basic understanding of the rules, the performance of a fan can be quickly calculated for various conditions.

There are three mathematical formula for fan law:

a) First fan law:

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} \ldots\ldots\ldots\ldots (1)$$

Where Q is the volumetric flow rate (cfm)

N is the fan rotating speed (rpm)

b) Second fan law:

$$\frac{P_{s1}}{P_{s2}} = \frac{P_{t1}}{P_{t2}} = \left(\frac{N_1}{N_2}\right)^2 \ldots\ldots\ldots\ldots (2)$$

Where P_s is the static pressure (psi)

P_t is the total pressure (psi)

N is the fan rotating speed (rpm)

c) Third fan law:

$$\frac{H_{b1}}{H_{b2}} = \frac{P_{t1}Q_1}{P_{t2}Q_2} = \left(\frac{N_1}{N_2}\right)^3 \ldots\ldots\ldots\ldots (3)$$

Where H_b is the brake power (W)

P_t is the total pressure (psi)

Q is volumetric flow rate (cfm)

N is the fan rotating speed (rpm)

These law are valid for the case where the pressure losses through all components of a ventilation system are proportional to the square of the velocity through that component (William A. Burgess, Michael J. Ellen Becker, Robert D. Treitman (2004). Ventilation for Control of the Work Environment, 2nd Edition. Hoboken, New Jersey: John Wiley & Sons, Inc). Fan law are practical for a fixed system and a non-modified fan. Other application to the system such as dampers will create a new system curve. It is due to pressure drop in the system cause by the damper.

During the HVAC system design process, the fan laws can be helpful in determining the correct fan criteria to be used for the system. Correct fan selection will lead to energy efficiency. The calculation made should consider all aspects especially the safety factors applied to the system. Evaluation should be made weighing the necessity of the safety factor of the fan. Figure 2.3 shows the fan curve graph for fan. The relationships of air flow to static pressure will not change unless the system itself is altered in some way. Static pressure always varies as the square of the change of airflow.

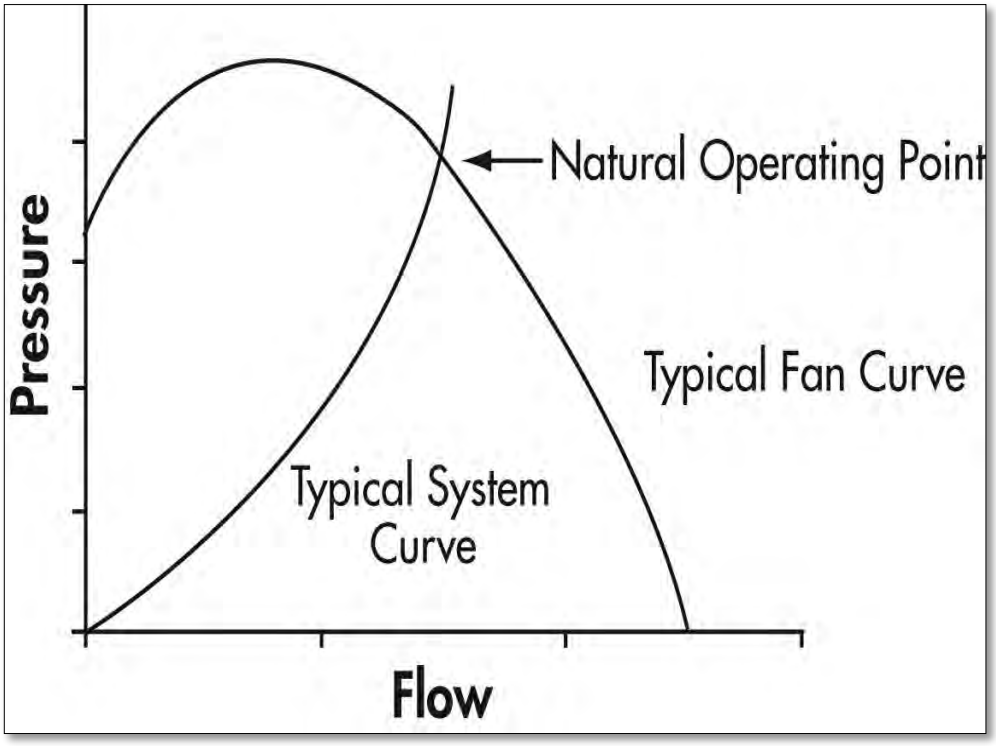

Figure 2.3: Fan Curve