MONITORING OF AIR DUCTING USING MECHANICAL ROBOT FOR INDOOR AIR QUALITY (IAQ) IMPROVEMENT

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PTTA UTHM
PERPUSTAKAAN TUNKU TUN AMINAH

A Thesis Submitted in
fulfillment of the requirement for the award of the
Degree of Master of Mechanical Engineering

Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia

December 2013

For beloved parents, Muhamad Damanhuri B Ahmad, and Rohaiyah Bt Hj Sulaiman, my siblings Muhd Ibrahim Bin Muhamad Damanhuri, Fatimahtuz Zahrah. Bte Muhamad Damanhuri ,Muhammad Hafizuddin Bin Muhamad Damanhuri, Muhammad Zulhusni Bin Muhamad Damanhuri, my fiancé Nur Afiqah bte Khairul Azhar, and all my friends.

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ACKNOWLEDGEMENT

The author would like to express his sincere appreciation to his supervisor, Associate Prof Dr Abdul Mutalib Leman for the kindness and supervision throughout the duration of this research. The appreciation is also given to the Co-Supervisor Dr Bukahri Manshoor for his supervision. The cooperation given by the Faculty of Mechanical and Manufacturing Engineering, Department at A4 building, Development and Property Management (PPH) of Universiti Tun Hussein Onn Malaysia (UTHM) for their kind cooperation during data collection during the study period. The author also would like to express high appreciation to his parents for moral support that never ends. Last but not least the author would like to express thankful to Abu Hurairah Zainuddin, Syafiq Syazwan Mustaffa, Hazriel Faizal Pahroraji, Nuur Azreen Paiman, Azian Hariri and Azizi Mohd Affandi for their help and collaborative work under Industrial Environment Research Group (IERG), Centre of Energy and Industrial Environment Studies (CEIES), UTHM.

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ABSTRACT

Indoor Air Quality (IAQ) has become public concern recently. Air ducting is used in Mechanical Ventilation and Air Conditioning (MVAC) system to deliver air to the building occupants. Without proper maintenance of the ducting system, it will affect the IAQ of overall building. Monitoring air ducting is the preliminary step to get real view inside the ducting. This study focused on the development of the Mechanical Ducting Robot (MerDuct) to monitor the ducting and data collection at real time (in-situ). The developments of the MerDuct have been performed in three phases. MerDuct were controlled wirelessly, and equipped with lamp and camera to get real visual inside the ducting. Case studies were visually performed suing MerDuct in three different scenarios namely full operation ducting, second is seldom operation ducting and third is abandoned ducting. Three case studies had been conducted in Block A4 Academic Office Building UTHM, Local Exhaust Ventilation (LEV) at Thermal Environmental Laboratory UTHM, and Building Services Laboratory Block E6, Faculty of Engineering Technology UTHM respectively. MerDuct was designed to be able travel to the various ranges along the ducting and using analog joystick to make it user friendly .The seldom operation of ducting was clearly shows clean ducting without any trapped dust and web since the LEV was only used once a week and it is only less than 1 year old. The other two scenarios clearly showed trapped dust and web from photo captured by MerDuct. From the experimental data, MerDuct was successfully performed as monitoring robot to detect Indoor Air Quality (IAQ) problem source. The image taken by MerDuct could help building owner to predict necessary time to perform the duct cleaning to improve the IAQ based on occupational safety and health for sustainable development.

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ABTRAK

Masalah kualiti udara dalaman (IAQ) menjadi kebimbangan umum pada masa kini. Salur udara digunakan bagi sistem Penghawa Dingin dan Pengudaraan Mekanikal (MVAC) untuk menyalurkan udara kepada penghuni bangunan. Penyelenggaraan salur udara yang lemah akan menjejaskan kualiti udara dalaman di keseluruhan bangunan. Pemantauan salur udara adalah langkah awal untuk mengetahui keadaan sebenar di dalam salur udara. Kajian ini memberi fokus kepada pembangunan robot (MerDuct) untuk memantau keadaan salur udara dan pengumpulan data di salur udara yang sebenar (in-situ). Pembangunan MerDuct telah dilakukan melalui tiga fasa. MerDuct boleh dikawal secara tanpa wayar, dilengkapi dengan lampu dan kamera untuk mendapatkan visual sebenar di dalam salur udara. Kajian kes telah di laksanakan di dalam tiga senario berbeza. Pertama, di salur udara yang beroperasi sepenuhnya setiap hari, kedua di salur udara yang jarang di gunakan dan ketiga di salur udara yang telah lama tidak beroperasi. Tiga kajian kes telah di jalankan masing-masing di Blok A4 Bangunan Pejabat Akademik UTHM, Sistem Pengudaraan Ekzos Setempat (LEV) di Makmal Persekitaran Terma UTHM dan salur udara di Makmal Pekhidmatan Bangunan Blok E6, Fakulti Teknologi Kejuteraan UTHM. Fasa ketiga MerDuct telah direka supaya ia dapat bergerak di dalam saiz salur udara yang pelbagai dan dengan menggunakan pedal permainan supaya ia lebih mesra pengguna. Salur udara yang jarang digunakan jelas menunjukkan salur udara yang bersih tanpa ada sangkutan habuk dan sawang kerana salur udara (LEV) itu hanya di gunakan seminggu sekali dan telah dibina kurang dari tempoh setahun. Dua lagi salur udara di Blok A4 Pejabat Pembangunan Akademik dan di Makmal Perkhidmatan Bangunan Blok E6 Fakulti Teknologi Kejuteraan jelas menunjukkan gambar habuk dan sawang yang tersangkut di dinding salur udara. Daripada keputusan kajian sebenar, MerDuct telah berjaya menjadi robot untuk memantau salur udara dengan jayanya untuk mengenal pasti punca masalah kualiti udara dalaman. Maklumat yang diperolehi daripada MerDuct boleh membantu pemilik bangunan untuk meramalkan masa yang sesuai untuk melakukan

pembersihan salur udara bagi meningkatkan kualiti udara dalaman berasaskan kepada keselamatan dan kesihatan pekerjaan untuk pembangunan lestari.

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LIST OF SYMBOLS AND ABBREVIATIONS

A	- Area
CAD	-Centre of Academic Development
Cfm	- Cubic feet per Minute
CO	- Carbon Monoxide
CO_2	- Carbon Dioxide
FKEE	- Faculty of Electric and Electronic Engineering
FKMP	- Faculty of Mechanical and Manufacturing Engineering
IAQ	-Indoor Air Quality
LEV	- Local Exhaust Ventilation
MerDuct	- Mechanical Robot Ducting
PIC	- Peripheral Interface Controller
PM	- Particulate Matter
PPH	- Development and Property Management
Ppm	- Part per million
PPS	- Centre of Postgraduate Studies
Q	- Flow Rate
TVOC	- Total Volatile Organic Compound
UART	- Universal Asynchronous Receiver/Transmitter
UTHM	-Universiti Tun Hussein Onn Malaysia
V	- Velocity
VB6	- Visual Basic 6
VOC	- Volatile Organic Compound

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter discusses the background of the research problem. It generally describes the importance of Indoor Air Quality (IAQ). This chapter also highlights the problem statement based on the background provided as well as the objectives, limitations and significance of the study.

1.2 Background of the Study

IAQ has become a major concern towards achieving healthy lifestyle. In this modern era people spend most of their time indoor. Basically, human will spend up to 90% doing activities indoor (Frontczak and Pawel Wargocki, 2011). Poor IAQ will affect occupant's health, and even productivity (L.T.Wong et al., 2009, R. Kosonen and F.Tan, 2004, Ajimotokan et al., 2009). Furthermore, poor IAQ can lead to the sick building syndrome (SBS) (Syazwan Aizat et al., 2009). The primary causes of poor IAQ is poor maintenance of air conditioning system and ventilation system. Pollution sources can be categorized into two: outdoor and indoor sources (Wan Rong & Kong Dequan, 2008). In commercial buildings, ducting is the primary source to deliver air to the rooms. Therefore ducting maintenance is essential to ensure the room served by the ducting and diffuser can be always supplied with clean air. However, some building owners ignore this aspect as duct monitoring and maintenance are quite expensive. Duct maintenance includes duct cleaning is an effective way to maintain the air duct to supply clean air

(Irtishad Ahmad et al., 2001, R.Holopainen et al., 2003). The building owner cannot afford to do the monitoring frequently and thus the IAQ of the building is in question (DOSH, 2010). Dust and toxic gases are the main issues in the IAQ parameters (A.M Leman et al, 2010a), while portable IAQ meter can only support for the ambient air monitoring (A.M Leman et al, 2010b). In this study the Mechanical Robot will be used to obtain visual images inside the ducting. The Mechanical Robot was developed by the Industrial Environment Research Group (IERG), Centre of Energy and Industrial Environment Studies (CEIES), Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia. Certain IAQ parameters inside the ducting will then be monitored to show actual condition in the duct.

1.3 Problem Statement

Poor indoor air quality will give negative impact to the building occupants. Some of the health problems related to poor indoor air quality are Sick Building Syndrome (SBS), Building Related Illnesses (BRI), and Legionnaire's disease. According to Fotoula P. Babatsikou (2011), SBS usually occurs in certain types of buildings that are served by automated heating, ventilation and air conditioning system. Poor IAQ due to microbial contamination can cause people eye incitement, asthma, allergic dermatitis, pneumonia, and even death (Wan Rong and Kong Dequan, 2008, Guoqing Cao,2008 and DOSH,2010). The major factor contributing to poor indoor air quality is poor maintenance of air conditioning and ventilation system including dirty duct. Therefore, a monitoring device should be developed to monitor the actual condition inside the duct so that the necessary maintenance work can be carried out.

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1.4 Objective of the Study

The objectives of the study are as follows,

i. To develop and fabricate more user friendly and affordable mechanical robot for air duct monitoring
ii. To examine the robot model performance in terms of camera range and travel range due to different control methods
iii. To qualitatively investigate the ducting conditions using mechanical robot.
iv. To quantify the level of IAQ parameters using mechanical robot in three different ducting operational conditions namely daily use duct, seldom use duct and abandon duct.

1.5 Scope of the Study

The scopes of study include the following,

i. The robot could travel in various range size of ducting.
ii. The robot must be equipped with lamp and camera.
iii. The robot operates wirelessly.
iv. Data communication between robot and user interface.

1.6 Limitations of Study

There are some limitations to complete this study as listed below,

i. The MerDuct has a certain distance limit to make it to operate wirelessly.
ii. The duct is made of galvanized iron and insulated with fibre glass which interrupts the communication between user and MerDuct.
iii. The MerDuct could not travel in vertical duct, and limited to the horizontal duct.
iv. The MerDuct could not climb when it is travelling at different height of ducting.

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1.7 Significance of the Study

The mechanical robot ducting (MerDuct) is used to inspect the conditions inside air ducting. The air ducting is designed and installed in various forms and sizes. Therefore, without proper equipment, it is almost impossible for human to have clear view of the condition inside the ducting. The ducting system is built during the building construction, and building owners are usually not aware on the cleanliness of the ducting. In maintenance industry, mechanical robot for duct cleaning is very expensive and has certain procedure to operate. The MerDuct has been developed to make it more users friendly and affordable so that more building owners can install and apply in their premises. The user and building owner would need mechanical robot that can be operate easily. Thus, the way to operate the MerDuct play an important role in the development of MerDuct.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature related to Indoor Air Quality (IAQ) and sources that contribute to poor IAQ. This chapter also looks into the related literature about mobile robot. A literature review is a stepping stone for current research. Any relevant ideas related to the research will help to provide better understanding towards achieving the improvement of current study.

2.2 Pollutant

Pollutant may come in either particles type or gaseous type. Both outdoor and indoor conditions may influence the surrounding IAQ. Pollution may come from various sources including outdoor pollution and indoor pollution sources. Microbes will come in two kinds including microorganism normally attached to airborne particle (10µm), and those exist due to activities such as coughing, sneezing and others. (Guoqing Cao, 2008 and Yu et. al, 2009).

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2.2.1 Outdoor Pollutant

Due to the urbanization, cars and motorcycles have become a major transportation for human economic activities. Fuel combustion will release a lot of hazardous gases to the surroundings and unfortunately are inhaled by human. The development of industry will also create air pollutions. Sulfur Dioxide (SO_2), Carbon Monoxide (CO), and many other toxic gases entering houses and work stations will influence the level of IAQ. Studies have been conducted to investigate the relation between industrial areas and the residential air quality. The indoor and outdoor pollution ratios of Carbon Monoxide and Particulate Matter (PM_{10}) are mainly affected by the outdoor sources origin (Fairus Muhammad Darus et al, 2009). By controlling outdoor pollutants from entering a building, it may have a significant effect in ensuring the occupants receive better air quality (Steven D.Campbell, 2007). In industry, dirty duct is caused by the outdoor pollutants.

2.2.2 Indoor Pollutant

There are many sources that can contribute to indoor pollutant. Indoor pollutant may come from building material, furniture and even from human body itself. Example of particle pollutants is dust from carpet and human's dead skin. Ornamental materials may come from building materials that can contribute to hazard and toxic compounds. For example wall painting will release harmful gases or contaminants. Humans also contribute to the pollution during the inhaling nd exhaling O_2 and CO_2, eating various types of food, and also producing other substances that can produce odor, sweat and many more (Wan Rong and Kong Dequan, 2008).

Most pollutants that are harmful and they include Carbon Monoxide (CO), Carbon Dioxide (CO_2), and Volatile Organic Compound (VOC) and that present in humans daily life. The growth of fungi and other microorganisms is related to the relative humidity and temperature. The rapid growth of those fungi is generally due to the high humidity environments. I.A Bamgbopa et al (2008) have studied on the growth

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of mold in building materials by using Digital Image Processing Technique. They concentrated on visual inspection of mold growth in buildings by applying four techniques to detect mold growth: image reprocessing, image segmentation, and mold analysis, and classification.

Some building materials and household products seem to be major source of indoor pollutions in house. Some parameters must be stressed such as Relative Humidity, Temperature, Formaldehyde, Benzene, Toluene, Ethyl benzene, Xylene, Styrene, and TVOC. Among those pollutants, Formaldehyde and Toluene are the main factor of indoor pollutant (Sun-Sook Kim, et al, 2006 and C. Yu and D. Crump, 1998).

2.3 Ventilation

There are two types of common ventilation which include mechanical ventilation and natural ventilation. Mechanical ventilation is performed and forced by influence of blowers or fans Natural ventilation on the other hand due to the air by natural air forces. Any room or occupied spaces must meet ventilation requirement of air change per hour (ACH) to control IAQ (Rim and Novoselac, 2010). ACH depends on the room size and its function or its specific requirement. Ventilation refers to the exchange of air inside any rooms or spaces to make sure the rooms have enough fresh air circulation. To ensure the spaces or rooms have good IAQ, they must bt equipped with appropriate ventilation system and proper maintenance of the system. Reducing ventilation rate will cause IAQ to be maintained at optimum quality (Memarzadeh, 2009).

Without proper ventilation system Total Volatile Organic Compound (TVOC) will increase. That clearly explains why ventilation is the best method to have good IAQ (Peter Rojeski & PE,1999 and Zuraimi et. al 2003). Dilution control can be used to reduce Volatile Organic Compound (VOC). Lack of ventilation is the main factor that contributes to the increase in concentration level of VOCs (Guoqing Cao, 2008). Ventilation is also an effective method to control microbial contamination. Meanwhile, by adding ultra violet germicidal irradiation (UVGI), non-familiar contaminants also be decreased (S.Loyd, 1995).

2.4 Ducting

Ducting is the medium to supply air from Air Handling Unit (AHU) to the room. Basically, most of dirt and particles will be suspended in the ducting (SMACNA, 1998 and ASHRAE Fundamentals, 2009). Since humidity in the ducting is higher than indoor concentration, the growth of mold is common in ducting. On the other hand in newly constructed site, duct is also often exposed to dust, and finishing work may also cause the dust to enter the duct (R.Holopainen et al, 2003). In most commercial building, galvanized steel were selected to build ducting system (John H. Stratton, 2000). The galvanized steel will gives consistency and esthetics to the building appearances.

2.4.1 Duct Monitoring

Ducting is the primary sources that deliver air to the room from the Air Handling Unit (AHU). It is basically made of galvanized iron. Most commercial and industrial building use ducting system to serve air conditioning and ventilation system for the building. It is more efficient than using single spilt unit system that will require a lot of considerations. The size of ducting generally depends on the air flow in the ducting. Ducting is not only used to supply cool air, but ventilation system also uses ducting as the medium to exhaust the air out of from the building. Figure 2.1 shows the condition inside the ducting if no regular maintenance such as duct cleaning and duct monitoring is conducted.

It is important to monitor ducting regularly. A lot of other contaminants will be trapped inside the ducting since ducting is the place where outside air, fresh air, and return air are mixed. In order to predict necessary time for duct cleaning, sensor and duct monitoring are so important. Appropriate practice of maintenance in Mechanical Ventilation Air Conditioning (MVAC) will result in consistently good thermal and ventilation control and reduce risk of biological control (Ajimotokan et al, 2009).

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