UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN, FABRICATE AND ANALYSE THE COCONUT FIBRE'S DUCT SILENCER FOR SOUND TRANSMISSION LOSS USING IMPEDANCE TUBE

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (REFRIGERATION AND AIR-CONDITIONING SYSTEMS) WITH HONOURS

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A thesis submitted
in fulfillment of the requirements for the degree of
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2022

DECLARATION

I declare that this project entitled “Design, Fabricate and Analyse Coconut Fibre’s Duct Silencer For Sound Transmission Loss Using Impedance Tube” is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

Name : Keshanraj A/L Ganesh

Date : 26/1/2022

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Refrigeration and Air-Conditioning Systems) with Honours.

Signature : .....

Supervisor Name : Ts. Muhammad Nur Bin Othman

Date : 26/1/2022

DEDICATION

I humbly dedicate this project to my beloved parents, late Mr. Ganesh and Mdm. Kohilambal, my siblings and to my friends. Not forget to dedicate this initiative to my respected supervisor, Ts. Muhammad Nur Bin Othman for guiding me through this project.

ABSTRACT

In a Heating, Ventilation and Air Conditioning (HVAC) system, noise generation in ducting of a building is still being an ongoing problem. The duct silencer is implemented with absorptive material that is made of synthetic fibre are still being used globally. Moreover, the usage of synthetic fibre as sound absorber in duct silencer give impacts to the health of the occupants other than harming the environment. In this research study, an analysis of sound transmission loss will be conducted for HVAC duct silencer that will be designed and fabricated. Coconut fibre as one of the natural fibres that can be easily obtained in our country will be used as the acoustic absorptive material. The aim of this study is to design the coconut fibre's duct silencer by using Solidworks software as well as to fabricate the design using 3D printer then to analyse the sound transmission loss of coconut fibre's duct silencer. A duct silencer was designed by using Solidworks software and then the design was transferred into 3D printer in numerical format. The material used to produce the duct silencer was thermoplastic called PETG. After the fabrication was done, the coconut fibre samples were inserted inside the slot and arranged into duct silencer and the impedance tube was used to investigate the sound transmission loss. Furthermore, 6mm thickness and 6 types of arrangements of coconut fibre in duct silencer was used in this research. As a result, a duct silencer with rectangular shape was designed and fabricated successfully using 3D printer. In this study, the greatest transmission loss obtained was 41.69dB at 4000Hz for 6 slot arrangement of coconut fibre. This research is expected to establish the use of natural fibre as a superior substitute for synthetic fibre as a sound absorptive material in duct silencers in the near future. This might be an approach to minimize the use of chemical products that are hazardous to humans and the environment.

ABSTRAK

Dalam sistem Pemanasan, Pengudaraan dan Penyaman Udara (HVAC), penghasilan bunyi dalam saluran bangunan masih menjadi masalah yang berterusan. Penyenyap saluran dilaksanakan dengan bahan penyerap yang diperbuat daripada serat sintetik masih digunakan secara global. Lebih-lebih lagi, penggunaan serat sintetik sebagai penyerap bunyi dalam penyenyap saluran memberi kesan kepada kesihatan penghuni selain membahayakan alam sekitar. Dalam kajian penyelidikan ini, analisis prestasi akustik akan dilakukan untuk peredam saluran HVAC yang akan dilukis dan dibina. Serat kelapa sebagai salah satu serat semula jadi yang mudah diperoleh di negara kita akan digunakan sebagai bahan penyerap akustik. Tujuan kajian ini adalah untuk melukis peredam saluran serat kelapa dengan menggunakan perisian Solidworks dan juga membina reka bentuk dengan menggunakan pencetak 3D kemudian untuk menganalisis Kehilangan Penghantaran Suara penyenyap saluran serat kelapa. Penyenyap saluran telah direka bentuk dengan menggunakan perisian Solidworks dan kemudian reka bentuk tersebut dipindahkan ke pencetak 3D dalam format berangka. Bahan yang telah digunakan untuk menghasilkan peredam saluran adalah termoplastik yang disebut PETG. Setelah fabrikasi selesai, sampel serat kelapa dimasukkan ke dalam slot dan disusun ke dalam peredam saluran dan tiub impedans digunakan untuk menyiasat kehilangan transmisi bunyi. Selanjutnya, ketebalan 6mm dan 6 jenis susunan serat kelapa dalam peredam saluran digunakan dalam penyelidikan ini. Hasilnya, peredam saluran dengan bentuk segi empat tepat direka bentuk dan dibina dengan jayanya menggunakan pencetak 3D. Dalam kajian ini, kehilangan transmisi terbesar yang diperoleh adalah 41.69dB pada 4000Hz untuk 6 susunan slot serat kelapa. Penyelidikan ini diharapkan dapat membuktikan penggunaan serat semula jadi sebagai pengganti unggul untuk serat sintetik sebagai bahan penyerap bunyi dalam penyenyap saluran dalam masa terdekat. Ini mungkin merupakan pendekatan untuk meminimumkan penggunaan produk kimia yang berbahaya bagi manusia dan alam sekitar.

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Last but not least, I want to express my heartfelt thanks to my wonderful parents and siblings for their everlasting love, support, and prayers. Finally, I'd want to express my gratitude to all my friends and individuals who helped, supported, and inspired me to begin my studies.

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LIST OF SYMBOLS AND ABBREVIATIONS

m	-	Metre
g/cm^3	-	Gram per cubic centimetre
MPa	-	Megapascal
%	-	Percentage
°C	-	Degree celcius
Wt.%	-	Weight percentage
mm	-	Millimetre
g	-	Gram
CO_2	-	Carbon dioxide
3D	-	3 dimensional
dBA	-	A-weighted decibels
dB	-	Decibels
PNC	-	Preferred Noise Criterion
SIL	-	Speech Interference Level
Hz	-	Hertz
cm	-	Centimetre
kV	-	Kilovolts
Kg/m^3	-	Kilogram per cubic metre
Ø	-	Diameter
PETG	-	Polyethylene Terephthalate Glycol
NaOH	-	Sodium hydroxide

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Noise defined as unnecessary or excessive sound that has negative consequences for human health, wildlife, and the environment. Long-term or elevated noise exposure has been linked to a variety of health issues, including physically and psychologically (Aluko and Nna, 2014). The heating, ventilation, and air conditioning (HVAC) system of a building is designed to offer thermal comfort for people, but it also generates noise that can be harmful to their mental health. Noise generation in HVAC system usually occurs in the ducting system of air handling unit (AHU) and noise that travels from one room to the next. However, noise can be generated by air passing through straight ducts and the effects of air moving through components such as bends, branches, mixing boxes, and so on (Madlan et al., 2017).

For the prevention of noise generation in the ventilation system, duct silencers or called absorptive silencers have been used to absorb the noise generated throughout the system. This silencer's main advantages are that it has good absorption at medium and high frequencies and is useful for narrow and broadband noise. When sound passes through the silencer, it converts a portion of the incident acoustic energy into heat by creating motion in the silencer's sound absorption material (Madlan et al., 2017). They are usually installed before the air diffusers, between the fan and the diffusing or exhaust fan. The absorptive fibrous material made of synthetic fibres like glass fibre and rock wool within the duct silencer will absorb the noise and convert it into heat.

However, these non-recyclable traditional absorptive materials have negative impacts on human's health in addition to harming the atmosphere and contribute to global warming by emitting CO2 (Mamtaz et al., 2016). Furthermore, acoustic panels consisting of glass wool and rock wool are quite expensive, and their abrasive characteristics might hurt humans when the dust from the panel is breathed (Yuhazri et al., 2019).

Coconut fibre is a CO2 neutral material and a renewable resource. Coconut fibre is abundant and inexpensive in Malaysia. Coconut fibre is biodegradable, low in density, and light weight. Lumen is a central hollow chamber placed in the unit cell's transverse section that acts as an acoustic and thermal insulator by lowering the bulk density of the fibre (Madlan, 2019).

In this research study, a HVAC rectangular duct silencer will be designed and fabricated by using the 3D printer, where the silencer will be made of thermoplastic material. Then, coconut fibre will be used as absorptive fibrous material to replace the usage of synthetic fibre as coconut fibre has various advantages. The sound transmission loss of the 3D printed duct silencer implemented with coconut fibre will be analysed in this research by utilising impedance tube method.

1.2 Problem Statement

Generally, HVAC system are utilised for the purpose of maintaining the indoor air quality inside the building so that the occupants can do their activities comfortably. However, the noise created in the ventilation system has been an issue besides the synthetic fibre that has been used in the silencer can cause many problems for the occupants in the building and environment. The most popular sound-absorbing panel materials utilised in the market include fibreglass, cotton, mineral fibre, polyester, and so forth.

However, fibreglass as a sound absorbent panel poses a serious health risk to people owing to fibreglass shedding. Furthermore, Mageswaran et al. (2019) and Ewe et al. (2021) stated that fibreglass has the potential to induce lung infection, skin and eye irritation, and pulmonary illnesses while manufacturing the synthetic fibreglass also contaminate the air and water with their waste materials. Yahya and Chin (2017) explained that synthetic fibre manufacturing was also particularly hazardous to the environment since it was created from high temperature industrial procedures such as hot extrusion. Moreover, the source of synthetic fibre is obtained from petrochemical sources, resulting in huge carbon footprints. As a result, this project concentrated on natural fibre to determine its acoustical performance in a duct silencer prototype.

1.3 Research Objective

The objectives of this research study are:

i. To design the duct silencer using Solidworks software.

ii. Fabricate the duct silencer using desktop 3D printer.

iii. To analyse the Sound Transmission Loss of coconut fibre's duct silencer using impedance tube.

1.4 Scope of Research

The scope of this research are as follows:

The project was initiated to develop a 3D printed rectangular duct silencer by using thermoplastic material named Polyethylene terephthalate glycol (PETG) and replacing synthetic fibre with natural fibre which was coconut fibre as a sound absorptive material. The goal of this project was to use Solidworks software and a 3D printer to design and

fabricate a rectangular duct silencer. This study examined the Sound Transmission Loss of a produced duct silencer with coconut fibre added to it by using impedance tube.

Next, the task breakdown began with the design and selection of the best duct silencer design, which was subsequently built using a 3D printer. The duct silencer then be fitted with coconut fibres on its rectangular slot, and the duct was connected to the impedance tube for acoustic performance testing.

The parameters observed when doing the analysis in this project was Sound Transmission Loss (STL). Meanwhile, the mass of coconut fibre utilised was 20g, the length, height, and width were 280mm x 84mm x 6mm, the thickness of the fibre was 6mm, and there were six different fibre arrangements.

During the outbreak, the timeline for completing this project was a constraint. As a result, this project never addressed air flow.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will include all the information that have been gathered and summarized from various resources like journals, articles, books and etc. It consists of studies that was done by past researchers regarding the noise pollution, applications of noise silencers, types of noise silencers, types of fibres used in noise silencers and the methods that have been used to obtain the results. These findings provide all the knowledge needed to guide the completion of the project.

2.2 Noise Pollution

Aluko and Nna (2014) stated that one of the environmental problems brought on by urbanisation is noise pollution that is increasingly becoming more prevalent, but it is often ignored. It does not seem to be as dangerous as other types of emissions, but it is an issue that has an effect on both human health and the environment. Noise pollution can be described or defined as noisy, unwanted, or unnecessary sound that has negative impacts on health of human being and environmental. Sravani et al. (2016) also stated that noise is just like poisonous chemicals in the atmosphere, is a pollutant that is becoming an increasingly important issue as a result of increased industrialization, the use of increasingly complex and voluminous machinery and equipment, and the acceleration of production. The permissible level of noise exposure for human health should be between 80 and 90 dBA, with 90 dBA and above being the danger limit with potential risk (Oviasogie & Ikudayisi, 2019).

Various factors of noise pollution results in various implications to the human and environment. Tabraiz et al. (2015) stated three traffic wardens at check posts near roads in the Pakistani cities of Taxila and Islamabad were chosen for the research survey regarding psychological and physiological effects faced by them. The researcher quoted that due to heavy traffic and high-pressure horns, noise levels (Leq) ranged from 86 to 106 dB for 8 hours and the estimated impulsive noise levels were up to 120 decibels which violates the OSHA regulations. The wardens faced major psychological impacts like aggravated depression, stress, public conflict, irritation and annoyance, behavioural affects, and speech interference. Hypertension, muscle tension, exhaustion, low performance level, concentration loss, hearing impairment, headache, and cardiovascular issues were found to be the physiological effects they faced. Purwaningsih et al. (2018) have quoted 96.5 percent of dental students on the UKM KL campus are exposed to noise pollution, which occurs mostly between the hours of 10 a.m. and 2 p.m. (65.3 percent). Students were irritated, had concentrating difficulties, and were stressed as a result of noise emissions, according to researchers. Vehicles were stated to be the significant source of noise in UKM's dental faculty. Furthermore, environment noise pollution may be a novel risk factor for pregnancy-related hypertension, particularly more severe variants of preeclampsia (Auger et al., 2018). He et al. (2019) also described that residential noise may be a risk factor for postpartum depression and other mental illness, especially when they were exposed to noise during night time.

Loud noise-induced hearing loss is a major cause of social noise exposure in manufacturing occupations. According to the findings of a brief survey conducted in Hyderabad's SITE area, the auditory effect of noise has a negative impact on humans, as deafness is 27 percent and auditory exhaustion is 22 percent, with the latter having the greatest health impact. A large proportion of the population suffers from sleep disturbances,

annoyance, poor performance in industrial workers' everyday lives, and a rise in hypertension associated with another cardiovascular related disease (Panhwar et al., 2018). Alimohammadi et al. (2018) explained the effects of long-term noise exposure on aggression in the employees of an automotive industry by selecting a random group of employees from different parts of paint shop to measure their aggression level using Buss and Perry's questionnaire. The relationship between the level of noise received by the group of employees and the level of aggression they expressed on the workplace was identified using linear regression analysis on Figure 2.1 below. Aggression levels were higher in those with more years on the job where this may be due to the effects of workplace noise and physical stressors. The interaction of noise volume and job tenure can also contribute to mental stress and devastating aggression in the workplace.

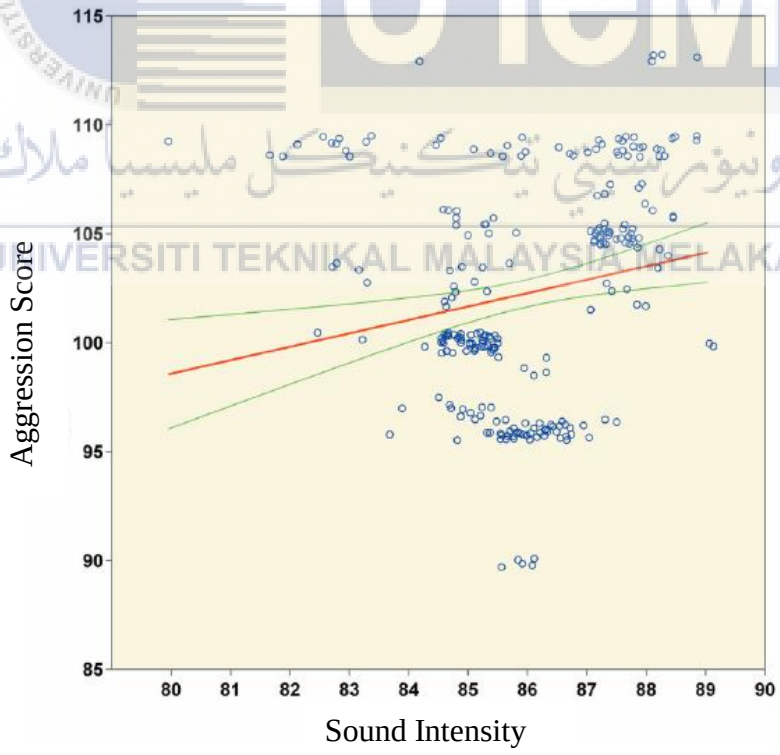

Figure 2.1 The aggression score of studied workers measured according to sound intensity, Alimohammadi et al. (2018)

Finally, Madlan (2013) explained that the Heating, Ventilating and Air Conditioning (HVAC) system has also contributed to a detrimental impact on the people in the building due to the noise it produces. He further explained that this scenario happens when the noise is transmitted into the room or building via the HVAC system through the duct, as well as directly from the noise source and the occupants in the room or building will be disturbed by the noise emitted through the HVAC duct wall.

2.3 Noise Silencers

Silencers, also known as sound attenuators, absorbers, or mufflers, are devices that are used to minimise the amount of noise that is transmitted from a source to a receiver (Bujoreanu & Benchea, 2017).

2.3.1 Noise Silencer in Power Plant

An underwater method of using a silencer that uses the concept of a jet pump was used to solve the excessive noise problem caused by discharging waste water of high temperature and pressure into air or water from nuclear power plants (Jie, Wei-Shi and Xian-Xing, 2010). On the other hand, Tupov (2013) have explained that the use of novel silencers for the most intensive noise sources at thermal power plants like steam exhausts, draught fans, gas turbines, hot-water boilers, transformers, and cooling towers was needed because the thermal power plants have a significant noise effect on the surrounding area. They allow a thermal power plant's noise to be reduced to acceptable levels. Kuz'minova and Tupov (2021) stated that acoustic insulation of gas pipes and noise barriers may be used to minimise noise from a gas pipeline and the noise reduction can only be achieved by combining acoustic insulation and noise barriers.