DESIGN OF SOUND PRO ACOUSTIC MATERIALS

ASYIQ ATAULLAH BIN SULAIMAN

FACULTY OF ENGINEERING

UNIVERSITI MALAYSIA SABAH

2022

DESIGN OF SOUND PRO ACOUSTIC MATERIALS

ASYIQ ATAULLAH BIN SULAIMAN

THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF MECHANICAL ENGINEERING

FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH

2022

UMS
UNIVERSITI MALAYSIA SABAH

DECLARATION

I now declare this, submitted to University Malaysia Sabah (UMS) as partial fulfilment of the degree of Bachelor Mechanical Engineering requirement, has not been submitted to any other university for any degree. I also certify that the work subscribed herein is entirely my own, except for quotation and summaries sources of which have been acknowledged.

The thesis may be available within the university library and photocopied or loaned to other libraries for consultation.

1 JULY 2022

____

ASYIQ ATAULLAH BIN SULAIMAN

(BK18110061)

CERTIFIED BY

____

IR. TS. MOHD AMRAN BIN HJ. MADLAN

SUPERVISOR

ACKNOWLEDGEMENT

First and foremost, I want to give The Almighty God a huge amount of praise and gratitude for His blessings throughout my life and for the success of the final year project. I am really appreciative of all the help I received over the course of these two semesters from various figures and individuals in order to finish my project.

Ir. Mohd Amran bin Madlan, my supervisor, deserves a lot of credit for allowing me to do the study on "Design of Sound Pro Acoustic Material" and for mentoring me throughout the entire Final Year Project (FYP) providing me with inspiration and guidance for doing this research. Without his acceptance of me as one of his FYP students, this project would not be feasible.

I would want to convey my thanks to my family, who were always there for me and helped me during the entire process of finishing my thesis. Last but not least, I want to express my gratitude to my friends for always encouraging me and supporting me no matter what. Sharing and gaining from memories and experiences. I also want to thank everyone who was directly or indirectly engaged in this study.

ABSTRACT

The problem of traditional sound absorption has not been fully solved during the previous 200 years. Its study has changed at every level in response to technological advancements and current demands in the actual world. Acoustic metamaterials (AMs) have drawn a lot of interest since there is still much to learn about them. The ability of technology to assist in resolving global issues has increased. As technology has advanced, 3D printers have been developed so that designers may design and produce a prototype. This is because the material used in 3D printers is sustainable. In this research, it will be focusing more on the simulations where the designs were done in SOLIDWORKS software, and the simulation will be executed using COMSOL Multiphysics. The material used to configure the simulation is polylactic acid (PLA) and stainless-steel where the stainless-steel plates will sandwich together with the design of the PLA. Three designs were created which is a lightweight sandwich-plate with embedded aperture, honeycomb, and disc. The research involves in finding the sound absorption coefficient, transmission loss as well as noise reduction coefficient (NRC). The greatest sound absorption coefficients are 0.8645, 0.9289, and 0.9805 for honeycomb, embedded aperture, and disc, respectively and for transmission loss are 4.3398, 5.4712, and 8.5528, respectively. The simulations were done with the design of embedded aperture is suitable for low frequency whereas the disc is suitable for high frequency. The NRC for the embedded aperture, honeycomb, and disc are 0.4318, 0.1903, and 0.2122, respectively.

ABSTRAK

Reka bentuk bahan akustik pro bunyi

Masalah penyerapan bunyi tradisional tidak dapat diselesaikan sepenuhnya dalam tempoh 200 tahun sebelumnya. Kajiannya telah berubah pada setiap peringkat sebagai tindak balas kepada kemajuan teknologi dan permintaan semasa dalam dunia sebenar. Bahan metamaterial akustik (AM) telah menarik minat ramai kerana masih banyak yang perlu dipelajari tentangnya. Keupayaan teknologi untuk membantu dalam menyelesaikan isu global telah meningkat. Memandangkan teknologi semakin maju, pencetak 3D telah dibangunkan supaya pereka boleh mereka bentuk dan menghasilkan prototaip. Ini kerana bahan yang digunakan dalam pencetak 3D adalah mampan. Dalam penyelidikan ini, ia akan memberi lebih tumpuan kepada simulasi di mana reka bentuk dibuat dalam perisian SOLIDWORKS, dan simulasi akan dilaksanakan menggunakan COMSOL Multiphysics. Bahan yang digunakan untuk mengkonfigurasi simulasi ialah asid polylactic (PLA) dan keluli tahan karat di mana plat keluli tahan karat akan sandwic bersama reka bentuk PLA. Tiga reka bentuk telah dicipta iaitu plat sandwic ringan dengan apertur terbenam, sarang lebah dan cakera. Penyelidikan ini melibatkan mencari pekali serapan bunyi, kehilangan penghantaran serta pekali pengurangan hingar (NRC). Pekali penyerapan bunyi yang paling besar ialah 0.8645, 0.9289, dan 0.9805 untuk sarang lebah, apertur terbenam dan cakera, masing-masing dan untuk kehilangan penghantaran ialah 4.3398, 5.4712 dan 8.5528. Simulasi dilakukan dengan reka bentuk apertur terbenam sesuai untuk frekuensi rendah manakala cakera sesuai untuk frekuensi tinggi. NRC untuk apertur tertanam, sarang lebah dan cakera ialah 0.4318, 0.1903 dan 0.2122, masing-masing.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Project Background

Sound is the production of an object that vibrates as it moves through a medium until they enter the human eardrum in physiology. In physics, it is produced in the form of a pressure wave. The air molecules vibrate, resulting in a chain reaction of sound wave vibrations. From the definition of physiology and physics, it can be deduced that vibration is the cause of sound as it quickly moves back and forth (up and down) about a point of equilibrium. In engineering terms, it is called acoustics, one of the branches of engineering that deals with sound and vibration (Penn State Engineering, n.d.).

In everyday life, there are many various sorts of sound, including audible, inaudible, unpleasant, pleasant, gentle, loud, and music (PASCO, n.d.). It may be relaxing to hear, but sure sounds can contribute to hearing loss anywhere, even in the workplace. Every year, 22 million people are exposed to potentially harmful noise at work, according to the (Centers for Disease Control and Prevention (CDC), n.d.). The public may also be exposed to potentially dangerous sounds, such as those produced by the monorail, train, or vehicle.

Harmful sound is dangerous, especially to our ears, as it can be susceptible as the frequency of the sound goes higher and potentially experience hearing loss. Under the Occupational Safety and Health Administration, (n.d.) of the United States Department of Labor, when the noise exposure is at or above 85 decibels averaged over eight working hours, employers must implement hearing conservation programs. The program aims to prevent initial occupational hearing loss and protect the remaining hearing.

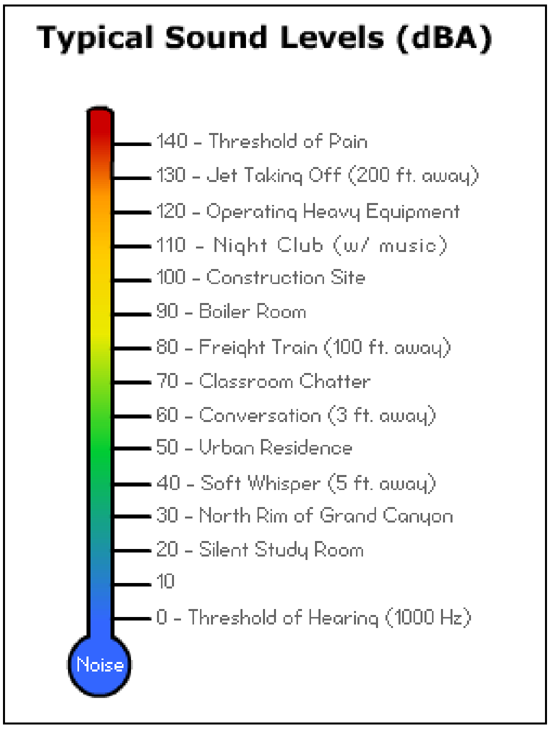

Figure 1.1 : The Sound Levels According to OSHA

Source : https://www.osha.gov/noise

There are many ways to reduce sound decibels, such as buying furniture, using an egg carton, or even using the acoustic panel studio foam. These items are related to acoustics materials (AMs). Acoustic Metamaterials are artificial constructions capable of altering sound's inherent properties (Forster, 2018). Acoustic Materials are widely used to increase the comfort and safety of their inhabitants, reducing noise generated inside and outside those spaces. It is an advancement of sound absorption and will continue to grow to get the absolute sound-absorbing materials.

AMs can be achieved using the metamaterial concept that manipulates and control light, sound, and other phenomena. A metamaterial is an artificially structured material that earns what nature could not. Metamaterials are identical elements made from materials like metals and non-conductive materials. Many researchers are doing a project on sound absorption that includes metamaterial. There is no end to the research because metamaterial has a vast combination of materials.

Therefore, this project involved designing a good pro sound using acoustic materials. Sound pro in this context means a soundproofing prototype. It ensures that the prototype is suitable for the industry or housing hazard.

1.2 Problem Statement

The world is expanding, and as a result, the noise will become an issue. Exposure to high decibel sounds, unpleasant to everyone, especially in a crowded location with constructions, industrial operations, and vehicles that generate a sound above the norm, can damage our coming generations. Amplitude, wavelength, and frequency are the three main categories that can be adjusted to limit sound production to the maximum extent possible.

There are various sound-absorbing materials available. However, they can only be used in specific settings such as homes and shopping centers. Metamaterials demonstrate that they can achieve more areas, and there are more depths to determine which metamaterial is the best for reducing noise while remaining non-harmful to the public. Metamaterial provides a large number of material combinations to choose from. As a result, determining the optimum material combinations for soundproofing will lessen the noise surrounding an area with loud noises.

Metamaterial plays a crucial function in sound absorption. Different materials, such as porous materials, have distinct characteristics that absorb sound. Not only through material selection but also through intelligent product design, decibel levels can be decreased. The material's construction ensures that the sound's speed slows down, lowering the noise level (Brooke et al., 2020).

The acoustic metamaterial absorbers are built and tested, focusing on low-frequency airborne sound absorption in linear and nonlinear regimes. The model's design needs a lot of consideration and standards to be followed to ensure the health and safety of the user.

This research uses metal because metal tends to have a low sound absorption coefficient. For example, steel has a sound absorption of 0.03. 3% of the sound is absorbed, whereas 97% is reflected throughout the area. Therefore, this research is to determine whether the design of sound pro can help increase the performance of sound absorption of steel.

1.3 Research Objectives

The primary goal of this research is to find the most effective sound absorption prototype utilizing metamaterial and determine which design is the most efficient for sound absorption. This project has a few goals that must be justify. The following are the goals:

1. To investigate the sound absorption coefficient, transmission loss and the noise reduction coefficient (NRC) of the three designs created;
2. To compare the designs performance for both absorption coefficient and transmission loss.

1.4 Scope of Work

In this project, the following is the scope of work planned to achieve the said objective and counter problems faced during the execution of the project. This project involves experiments, simulation, and analyzing the sound absorption performance of the pro sound design of AM acoustic materials. The scope of work involves

A. Preliminary Literature Review
   Investigate past research on sound absorption using acoustic materials to strengthen the knowledge on this project.

B. Determine the Metamaterial
   Choosing the suitable helps more in increasing the quality of the prototype. Hence, the acoustic material will be used with at least one metamaterial.

C. Design the prototype.

SOLIDWORKS software will be used to design the model. The prototype can be compared for each metamaterial used before fabricating the prototype in the software.

D. Finite Element Method (COMSOL software)

COMSOL MULTIPHYSICS will be used to simulate this project. It is used for general purposes and numerically solves various mechanical problems. The frequency of the noise is from 0 – 6000Hz.

E. Documentation of data.

The data from the research will be documented in report form will and presented regarding the findings from the research

1.5 Research Methodology

This project focus on both simulation and experimenting. The outcome analysis will be compared for each metamaterial. The project will be carried out as follows:

I. Selection of metamaterial

The metamaterial selection is crucial to ensure that the materials are correctly chosen, suitable for sound absorption, and not harmful to the environment.

II. Design of the Prototype

The design of the prototype is to make sure that the design is done according to the standard and that it can reduce as much sound as possible using SOLIDWORKS software.

III. Simulating and Collecting Data.

The experiment involves sound absorption performance from the prototype based on the Sound Absorption Coefficient, α, of each metamaterial. Experiments and simulations will be applied for the data collection. The data will be recorded to compare the performance of each metamaterial.

A summary of the methodology is shown below.

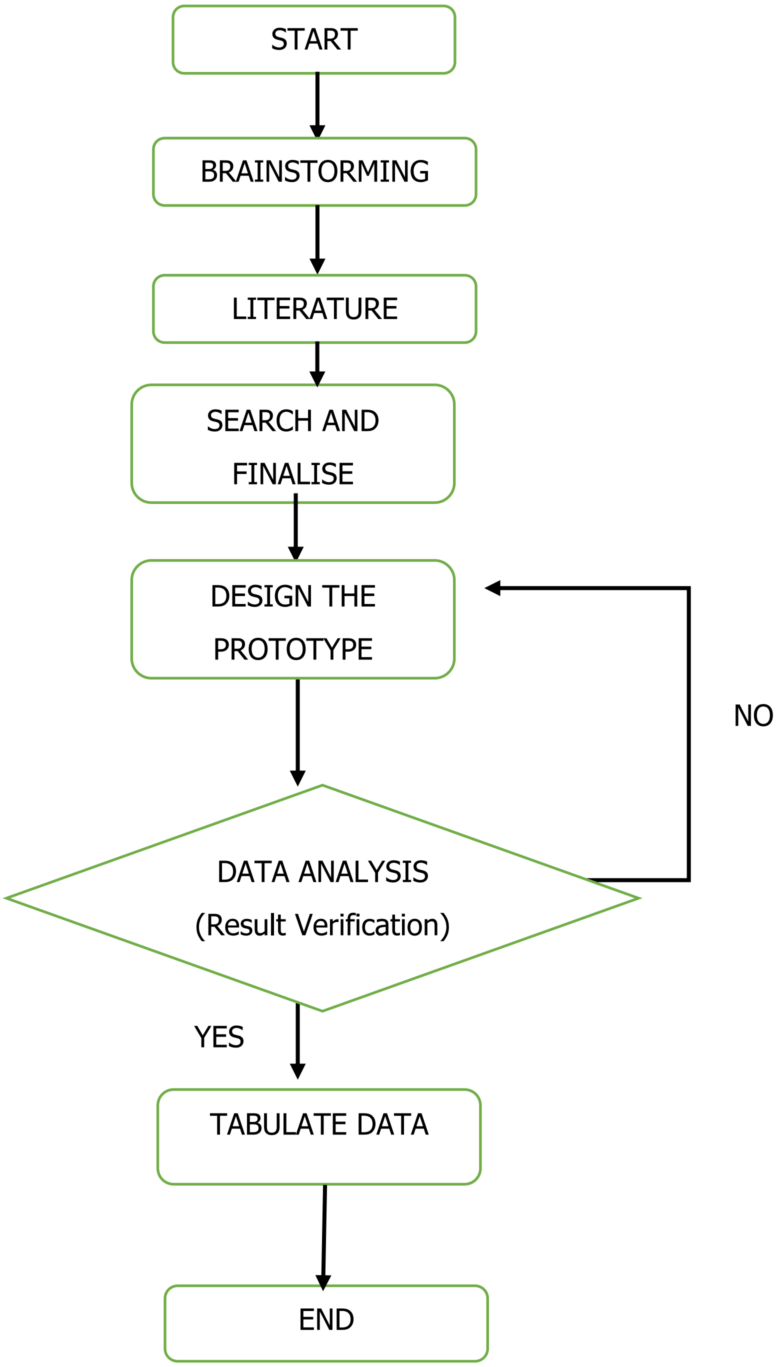

Figure 1.2 : Research Flowchart

CHAPTER 2

LITERATURE REVIEW

2.1 Limitation of Noise Exposure in Society

According to American Speech-Language-Hearing Association (ASHA), sounds that are louder than 85 dBA can cause hearing loss. The safe listening time in half for every 3-dB increase in noise levels above 85 dBA. For example, people can listen to noises at 85 decibels for 8 hours.

Listening to the same sounds for 4 hours is safe if the volume reaches 88 dBA. If the sound increases to 91 decibels, your safe listening duration is reduced to two hours. Lowering the decibels for the surrounding is crucial to ensure that the people in the area are safe from harmful noises.

The sound of 85dBA can be reduced by using a sound absorption product with a proper choice of material. Now, most researchers are recommending acoustic metamaterials for sound-absorbing material. Acoustic metamaterials bring new life into a long-forgotten acoustic application: sound absorption.

2.2 Acoustic Metamaterial

2.2.1 Introduction

Acoustic Metamaterials are manufactured constructions capable of altering sound’s inherent properties. They are composed of composite materials that allow vibrational waves' dispersive qualities to be controlled (Deymier, 2013). Acoustic Metamaterial can be further defined as composite materials typically composed of arrays of small metallic resonators structured on the microscale or nanoscale (Argyros et al., 2015).

In the last ten years, acoustic metamaterials have been developed with purposefully created microstructures to achieve exotic physical phenomena such as negative effective refraction index, effective negative density, effective negative modulus, and omnidirectional sound absorption (Gao & Hou, 2018).

The properties of acoustic metamaterials include an acoustic wave's debilitation or 'bending.' Acoustic metamaterials give new insights by making it easier to determine broad working bands, low-frequency absorption, and high absorption with the thin thickness (Xiuhai Zhang et al., 2020).

In recent years, researchers have proved the effectiveness of numerous hybrid meta-surface absorbers, which combine the classic perforated plate with subwavelength-sized meta-structures (Kumar & Lee, 2019). These manufactured materials can alter the inherent properties of electromagnetic and acoustic waves. Anything that looks to defy nature's laws will inevitably pique people's interest, not just in academics but also in public.

Metamaterials can be created to alter electromagnetic, acoustic, or elastic waves in novel ways, allowing for new capabilities like invisibility cloaking (Pendry et al., 2006). According to Forster (2018), in the acoustic field, the applications of metamaterial are:

- Transformational acoustic devices – through wave manipulation.
- Acoustic diffraction gratings - used to scatter sound energy to one or more angles.
- Acoustic 'cloaking' - When acoustic energy collides with an object, it reacts as if it isn't there.
- Wave reduction and resistance devices.

Acoustic metamaterial designs grow and diversify in size, form, and variety. This growth may be traced back to a breakthrough in acoustic metamaterials in 2000 when Hong Kong University of Science and Technology researchers created locally resonant sonic crystals (Liu et al., 2000). Bruel & Kjaer's two-microphone impedance measurement tube modified the study to measure sonic transmission.

Researchers have been modifying metamaterial and its principles using metamaterial to demonstrate sound absorption over the past two decades. Researchers have developed various ways to use structures or build acoustic metamaterials. Some researchers are experimenting with an acoustic metamaterial that can be printed using a 3D printer.

2.2.2 Pancake Absorber Design

A pancake absorber with a few centimetres thickness is helpful for low-frequency sound absorption (Brooke et al., 2020). The design is similar to that of a pancake absorber, but there are significant differences, such as periodically arranged metallic plates with the central perforation.

They are mechanically robust and include no fibrous or foamed elements. This qualifies them for usage in hostile conditions, alongside microperforated absorbers, to attenuate high amplitude noise (Brooke et al., 2020). The frequency dependence of the absorption coefficient is predicted using a transfer matrix model (TMM), which agrees well with the results.

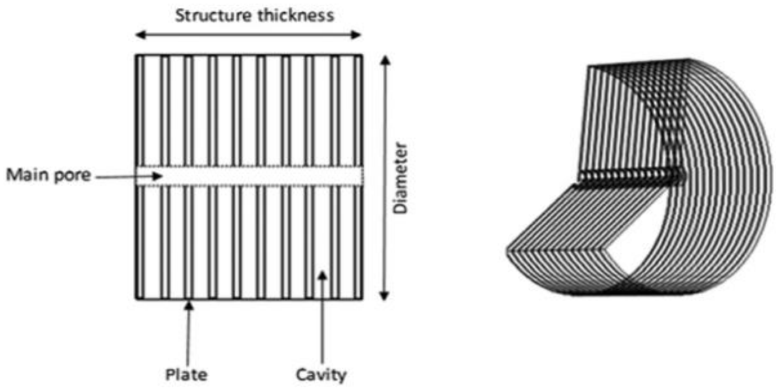

Figure 2.1: Pancake absorber structure

Source : Brooke et al., (2020)