**SOUND ABSORPTION PERFORMANCE OF ACOUSTIC METAMATERIAL**

**AMIR HAZIQ BIN ZAHARI**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

# SOUND ABSORPTION PERFORMANCE OF ACOUSTIC METAMATERIAL

**AMIR HAZIQ BIN ZAHARI**

**This report is submitted**
**in fulfilment of the requirement for the degree of**
**Bachelor of Mechanical Engineering (Plant and Maintenance)**

**Faculty of Mechanical Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**JANUARY 2021**

**DECLARATION**

I declare that this project report entitled "Sound Absorption Performance of Acoustic Metamaterial" is the result of my own work except as cited in the references

| | | |
|---|---|---|
| Signature | : | .......................................... |
| Name | : | .......................................... |
| Date | : | ........................................... |

## APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Plant and Maintenance).

Signature :. ..................................

Name of Supervisor : ..................................

Date : ..................................

## DEDICATION

To my beloved mother and father

## ABSTRACT

Acoustic metamaterial is a manmade artificial structure that arranged repetitively with having its own characteristic and properties. Acoustic metamaterial is one of the new designated structure used for sound absorption application. Various designs have been created from past researcher in purpose to produce an effective structure for sound absorption. For years, natural materials have been used for research and application in many fields especially in sound absorption purpose. In long terms, the continuous uses of this material will harm the natural resources. Modern technologies such as CAD software and 3D printing technology have a great potential to overcome this problem in future. The aim of this research is to utilize the CAD software in designing and producing 3D model of acoustic metamaterial by using 3D printing technology. The 3D printed metamaterial is tested in lab experiment and the sound absorption performance is observed. The 3D printed metamaterial is made of ABS material. ANSYS software is used to determine the natural frequency of the metamaterial for lab experiment requirement. Impedance tube method is used to study the sound absorption performance. PHOTON analyzer and MATLAB are used to collect and interpret the data from the experiment. The result indicates that the 3D printed metamaterial able to work well in absorbing sound especial at low frequency and high frequency. The sound absorption performance at low frequency is dissimilar for all the samples because of the different in design. Furthermore, the effectiveness of the samples in absorption performance can be improve by increasing the cavity depth which is the air gap in impedance tube. The sound absorption performance at low frequency and the absorption peak improved and better result can be obtained.

# *ABSTRAK*

*Metamaterial akustik adalah struktur buatan yang disusun berulang-ulang dengan mempunyai ciri dan sifat tersendiri. Metamaterial akustik adalah salah satu struktur baru yang digunakan untuk aplikasi penyerapan bunyi. Pelbagai reka bentuk telah dibuat dari penyelidik masa lalu dengan tujuan untuk menghasilkan struktur yang berkesan untuk penyerapan bunyi. Selama bertahun-tahun, bahan semula jadi telah digunakan untuk penyelidikan dan aplikasi dalam banyak bidang terutama untuk tujuan penyerapan bunyi. Dalam jangka masa panjang, penggunaan bahan ini secara berterusan akan merosakkan sumber semula jadi. Teknologi moden seperti perisian CAD dan teknologi percetakan 3D berpotensi besar untuk mengatasi masalah ini pada masa akan datang. Tujuan penyelidikan ini adalah untuk menggunakan perisian CAD dalam merancang dan menghasilkan model 3D metamaterial akustik dengan menggunakan teknologi percetakan 3D. Metamaterial bercetak 3D diuji dalam eksperimen makmal dan prestasi penyerapan bunyi diperhatikan. Metamaterial bercetak 3D diperbuat daripada bahan ABS. Perisian ANSYS digunakan untuk menentukan frekuensi semula jadi metamaterial untuk keperluan eksperimen makmal. Kaedah tiub Impedansi digunakan untuk mengkaji prestasi penyerapan bunyi. Penganalisis PHOTON dan MATLAB digunakan untuk mengumpulkan dan mentafsirkan data dari eksperimen. Hasilnya menunjukkan bahawa metamaterial bercetak 3D dapat berfungsi dengan baik dalam menyerap bunyi utama pada frekuensi rendah dan frekuensi tinggi. Prestasi penyerapan suara pada frekuensi rendah tidak sama untuk semua sampel kerana reka bentuknya berbeza. Selanjutnya, keberkesanan sampel dalam prestasi penyerapan dapat ditingkatkan dengan meningkatkan kedalaman rongga yang merupakan jurang udara dalam tabung impedans. Prestasi penyerapan suara pada frekuensi rendah dan puncak penyerapan bertambah baik dan hasil yang lebih baik dapat diperoleh.*

# ACKNOWLEDGEMENT

"In the name of Allah S.W.T, the Most Merciful and the Most Compassionate"

First and foremost, I am very thankful to the Almighty Allah S.W.T for giving me the strength and opportunity to successfully completing this project. Next, my gratitude and thanks go to my supervisor, Prof. Datuk Ir. Ts. Dr. Mohd Jailani Bin Mohd Nor for his guidance, support and valuable suggestion throughout the completion of this project. Without his assistance and guidance, this research will not be able to be done successfully within the time given.

Furthermore, I would like to thank both of my parents which are Zahari Bin Mohd Din and Norhayati Binti Ahmad jemadi for their sacrifices, guidance, love and support throughout my bachelor's degree journey and also completion of this project. A special thanks to my partner for the moral support and sharing ideas which contribute as well to this project. Finally, great thanks for those who have supported and helped me directly or indirectly throughout this research.

# TABLE OF CONTENTS

**PAGE**

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| ABS | Acrylonitrile Butadiene Styrene |
| NRC | Noise Reduction Coefficient |
| STL | Sound Transmission Loss |
| PLA | Polylactic Acid |
| CAD | Computer-Aided Design |

## LIST OF SYMBOLS

| | | |
|---|---|---|
| Ei | = | Incident Energy |
| Er | = | Reflected Energy |
| Ea | = | Absorption Energy |
| $\alpha$ | = | Absorption Coefficient |
| $R^2$ | = | Reflectance |
| $T^2$ | = | Transmittance |
| t | = | Transmission Amplitude |
| Wn | = | Natural Frequency |
| k | = | Stiffness |
| m | = | Mass |

# CHAPTER 1

# INTRODUCTION

## 1.0 Background Study

Acoustic absorption which is also known as sound absorption becoming one of important needs in human life. The demand for isolating air noise has been increase across the year as it caused negative effect to human daily life. People will be exposed to congestion of air noise coming from road and traffic for a long time. Thus, this can cause health issues such as mental illness and sleep disorder. For worst case, this undesirable noise may cause deafness to the people that work with noisy machine. In acoustic and mechanical engineering, one of the important topics is sound absorption. A lot of material has been used for this noise isolation process. Fibrous material and rubber are the examples good insulation material that commonly used to increase noise absorption. Sound absorption process can enhance quality life and increase the productivity for human life (Badreddine Assouar et al. 2016).

Sound absorption properties of the material is one of the important things need to be considered in acoustic design. Sound absorption defined as sound energy that pass through a surface but then converted into some other energy such as heat and mechanical energy. Absorbent can be divided into three types which is porous material, membrane absorber and Helmholtz resonators. Porous materials often used in acoustic absorption as it has degree of absorption for all frequencies. Knowledge in absorption characteristics is important for acoustic design to avoid unexpected error and vary result (RBW Heng, 1988).

Metamaterial research becoming popular and hot issue among researchers around the world. Metamaterial is an artificially made material which being applied in acoustic and electromagnetic field. The repetitive arrangement in this material able to produce unique and different properties that cannot be found in conventional materials. The properties for this metamaterial do not from the base material but based on the newly designated structure in terms of shape, arrangement, size, and geometry. For each arrangement of nanoscale unit cell will give out different properties and functionalities depends on the researcher desire.

## 1.1 Problem Statement

For years, many researchers only focus on sound absorption by using natural insolation materials. Kenaf, glass wool and coco fiber are the example of this insulation materials that have been used before. Nowadays, a lot of technologies and software have been created for better process such as finite element analysis. This software currently being used world widely and capable to create any shape and geometry. The purpose of this project is to study and determine the capability of metamaterial in sound absorption application. The properties in metamaterials and its application still not widely used for engineering fields. By using this software, various geometry shape can be designed and the capability of metamaterials in enhancing sound absorption can be studied.

## 1.2 Objectives

1. To design metamaterial structure for sound absorption by using computer-aided design (CAD) software.
2. To study sound absorption performance of the metamaterials from the experiment.

## 1.3 Scope of Project

The scopes of this project are:

1. The design of metamaterial structure is based on honeycomb pattern and other possible pattern.
2. Conduct the experiment in lab by using impedance tube and PHOTON data analyzer.
3. The metamaterial is designed by using ABS material and other material that is suitable in 3D printing.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

In this chapter, literature review is explained by referring to the journal, article and other materials relate to this project. Literature study is presented regarding to some topic such as noise, sound absorption, metamaterials, and acrylonitrile butadiene styrene (ABS) materials. The purpose of this chapter is to provide better understanding on sound absorption performance by using metamaterial structure.

## 2.2 Noise and Sound

Noise usually described as undesirable sound which give psychological effect to people and surrounding. Noise can be categorized into disturbing noise and noise nuisance. Noise which is surpass the rating level by 7 dBA or surpass residual noise level by 3 dBA is categorized as disturbing noise. Decibels (dB) is the measurement used for sound level. For sound to be heard, the air pressure changes should complete a cycle at least 20 times per second. There is different type of sounds in surrounding such as:

- Continuous sound
- Varying sound
- Intermittent sound
- Impulsive sound

Some noise can also give negative impact to people which indicate the increasing environmental health problem. Hearing loss and poor quality of are the examples of the negative impact. Noise level at 140 dB is the maximum range of sound for human. This noise range is not recommended for a long time as it will give negative impact on hearing (capetown,2013). Figure 2.1 below shows the table of typical everyday noise levels.

| TYPICAL EVERYDAY NOISE LEVELS | | |
|---|---|---|
| **DECIBELS (dB)** | **COMMON SOUNDS** | **PERCEPTION** |
| 10 dB - 30dB | Whisper or a quiet conversation | Barely audible |
| 30dB - 50dB | Rainfall, quiet office, refrigerator or a computer | Heard faintly |
| 50db - 60db | Dishwasher, normal conversation or a radio | Moderate level |
| 60dB - 70dB | Hairdryer, heavy traffic or a ringing phone | Moderate to loud |
| 70db - 80dB | Noisy office or an alarm clock | Loud |
| 80dB - 90dB | Electric razor, lawnmower or an vacuum cleaner | Loud to very loud |
| 90dB - 100dB | Chain saw, air compressor or a jackhammer | Very loud |
| 100dB - 110dB | Rock concert, power saw or a hifi on full | Extremely loud |
| 110dB - 120dB | Jet take off, nightclub or thunder | Extremely loud to painful |
| 120dB - 130dB | Shotgun | Painful |

Figure 2.2(a): Table of Typical Everyday Noise Levels.

Sound or noise has its very own characteristic which is frequency and loudness. Frequency of sound usually measured in unit hertz (Hz). Sound is known as changes of pressure wave that travel through a medium. The pressure changes per second is known as frequency of sound. The higher the frequency of sound, the higher pitched a sound is felt. Human audible hearing range is from 20 to 20000 Hz and become very sensitive at 2500 to 3000 Hz.

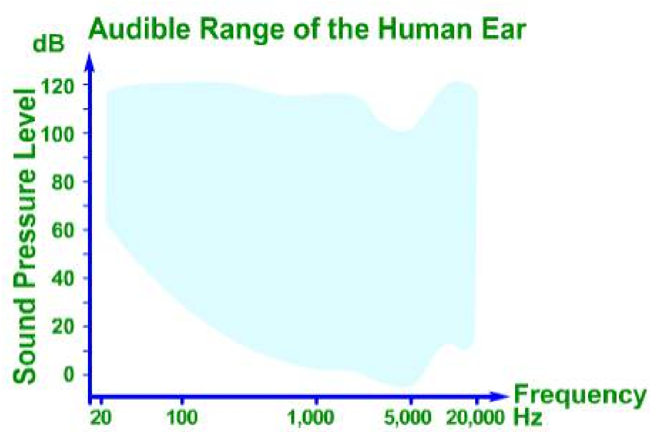


Figure 2.2(b): Audible Range of The Human Ear (Department,2010).

Another characteristic can be found in sound is the loudness. In general, loud noise will indicate high changes in pressure and low noise has low changes. This changes in pressure are measured in unit Pascal which is Pa. However, this measurement unit is not convenient with high sound pressure. Due to that, micro Pascal which is μPa being used for most cases in determining the sound pressure (Department,2010). Figure 2.3 below shows the example of sound pressure measured in unit micro Pascal.

| Source of Sound/Noise | Approximate Sound Pressure in μPa |
|---|---|
| Launching of the Space Shuttle | 2,000,000,000 |
| Full Symphony Orchestra | 2,000,000 |
| Diesel Freight Train at High Speed at 25 m | 200,000 |
| Normal Conversation | 20,000 |
| Soft Whispering at 2 m in Library | 2,000 |
| Unoccupied Broadcast Studio | 200 |
| Softest Sound Human can Hear | 20 |

Figure 2.2(c): Table of Example Sound Pressure Measured in Unit Micro Pascal.

A study was conducted in an article of "*influence of noise sensitivity on annoyance of indoor and outdoor noises in residential buildings*" by Jong Kwan Ryu. et al. in 2010 to examine the different indoor and outdoor sources of noises that give negative impact to people. Sources of noise can be categorized into indoor and outdoor. Indoor noise defined as noise come from residual areas while outdoor noise is come from traffic and transportation. To determine the sensitivity of the noise, indoor noise such as floor impact, airborne noise and drainage noise are included. For the outdoor noise, traffic and transportation noise are considered. The correlation coefficient for indoor noise is higher than the outdoor noise which mean most people are sensitive more to indoor noise rather than outdoor noise. Lower noise exposure becomes a very important consideration that influenced people. Thus, improvement in building insulation will be an important aspect for living in the future.