SIMULATION OF SOUND ABSORPTION PERFORMANCE OF AM ACOUSTIC MATERIALS

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FACULTY OF ENGINEERING
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DECLARATION

I hereby declare that this thesis, submitted to Universiti Malaysia Sabah (UMS) as partial fulfilment of the requirement for the degree of Bachelor of Mechanical Engineering, 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 duly acknowledged.

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25 JULY 2022

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ABSTRACT

Over the past 200 years, the classic sound absorption issue has not been solved, and its research has been modified at every stage in response to real-world needs and modern technologies. Acoustic metamaterial has been introduced in order to improve the classic sound absorption material. Due to their significant research and development over the previous 30 years, acoustic metamaterials (AMs) have gained interest. The traditional sound absorption challenge of determining broad operating band and low-frequency absorption is given new life by utilizing these materials in particular. These studies aim to determine which material that have suitable acoustical properties to be design as acoustic metamaterial for sound absorption and obtain the sound absorption coefficient of the Acoustic Metamaterial and investigate which have best sound absorption performances. In this study an Aerogel, ceramic foam, and metal foam will be tested to be a metamaterial with a design of sandwich structure and honeycomb core structure. This is to overcome the world's noise problem that lately become worse as a result of population growth. These configuration and material proven can give better sound absorption performance. The analysis of these research is conducted in SOLIDWORKS as the model design software and COMSOL Multiphysics as the simulation software for the acoustical behavior of the metamaterials and configurations. The parameters that measured is the sound absorption coefficient, to determine the performance of the acoustic metamaterials. These study results proven that Aerogel metamaterial is the most performing material to absorb sound and in lower frequencies and high frequency range as it has maximum sound absorption coefficient of 0.9779 at low frequency and 0.9998 at high frequency while the other metamaterial which is ceramic, and metal have 0.9239 and 0.5424 respectively at low frequency and 0.9959 and 0.9218 respectively at high frequency.

ABSTRACT

SIMULASI PRESTASI PENYERAPAN BUNYI BAHAN AKUSTIK AM

Sepanjang 200 tahun yang lalu, isu penyerapan bunyi klasik tidak dapat diselesaikan, dan penyelidikannya telah diubah suai pada setiap peringkat sebagai tindak balas kepada keperluan dunia sebenar dan teknologi moden. Metamaterial akustik telah diperkenalkan untuk meningkatkan bahan penyerapan bunyi klasik. Disebabkan oleh penyelidikan dan pembangunan penting mereka sepanjang 30 tahun sebelumnya, bahan metamaterial akustik (AM) telah mendapat minat. Cabaran penyerapan bunyi tradisional untuk menentukan jalur operasi yang luas dan penyerapan frekuensi rendah diberi kehidupan baharu dengan menggunakan bahan-bahan ini khususnya. Kajian ini bertujuan untuk menentukan bahan yang mempunyai sifat akustik yang sesuai untuk direka bentuk sebagai metamaterial akustik untuk penyerapan bunyi dan mendapatkan pekali penyerapan bunyi Metamaterial Akustik dan menyiasat yang mempunyai prestasi penyerapan bunyi yang terbaik. Dalam kajian ini Aerogel, buih seramik, dan buih logam akan diuji untuk menjadi metamaterial dengan reka bentuk struktur sandwic dan struktur teras sarang lebah. Ini bagi mengatasi masalah kebisingan dunia yang kebelakangan ini menjadi lebih teruk akibat pertambahan penduduk. Konfigurasi dan bahan ini terbukti boleh memberikan prestasi penyerapan bunyi yang lebih baik. Analisis penyelidikan ini dijalankan dalam SOLIDWORKS sebagai perisian reka bentuk model dan COMSOL Multiphysics sebagai perisian simulasi untuk kelakuan akustik bahan dan konfigurasi. Parameter yang diukur ialah pekali penyerapan bunyi, untuk menentukan prestasi bahan metamaterial akustik. Hasil kajian ini membuktikan bahawa metamaterial Airgel adalah bahan yang paling berprestasi untuk menyerap bunyi dan dalam frekuensi rendah dan julat frekuensi tinggi kerana ia mempunyai pekali penyerapan bunyi maksimum 0.9779 pada frekuensi rendah dan 0.9998 pada frekuensi tinggi manakala metamaterial lain iaitu seramik, dan logam. mempunyai 0.9239 dan 0.5424 masing-masing pada frekuensi rendah dan 0.9959 dan 0.9218 masing-masing pada frekuensi tinggi.

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LIST OF ABBREVIATION

UMS	University Malaysia Sabah
AMs	Acoustic MetamaterialsThree Dimension
3D STL	Sound Transmission Loss

CHAPTER 1

INTRODUCTION

The first chapter describes an overview of sound absorption performance Acoustic Metamaterial. This chapter covered the introduction, problem statement, objectives, scope of works and research contributions.

1.0 Introduction

As a result of the growth in population, the world's noise problem has recently gotten worse. Noise pollution is one of the most dangerous types of pollution since it is an unpleasant sound. The spread of modern industrial operations and forms of transportation such as airplanes, trains, automobiles, and buses are the primary causes of noise pollution in metropolitan areas. Furthermore, human daily activities contribute significantly to the generation of noise levels that can bother others.

Furthermore, noise's physiological and psychological effects on humans have been well investigated (Atmaca et al., 2005). Emotional irritants, such as eagerness, insomnia, anxiety, and tension, are linked to the psychological effect (Saeki et al., 2004). Long-term exposure to high noise levels has been related to psychological and physiological consequences. Because of its harm to people, noise reduction is necessary to create an acoustically pleasant workplace.

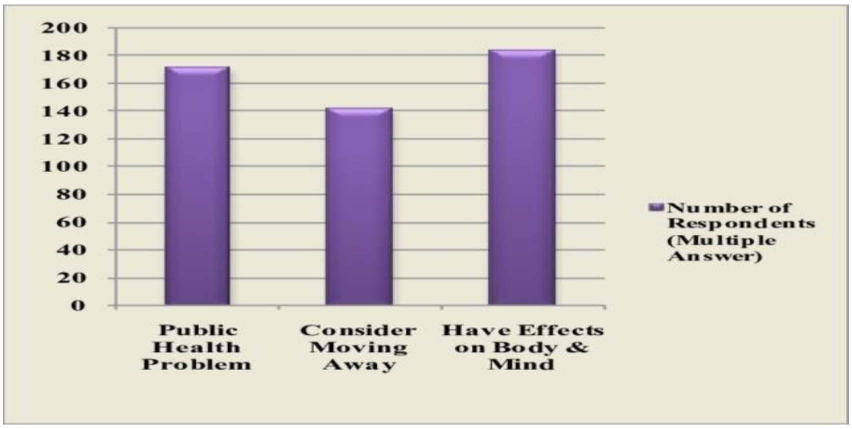


Figure 1.1: Public Response about Seriousness of Noise Pollution

Source: Muhit, I. B., & Chowdhury, S. T. (2013).

The quantity of energy extracted from a sound wave is measured by the wave traveling through the thickness of a material (Shrivastava, 2018). While propagating from air into an absorption medium, the sound wave may be reflected or absorbed, resulting in the loss of energy and damping effects. The conversion of sound waves into heat causes sound absorption in a polymeric material. Sound absorption is critical for soundproofing. Sprayed polymers are recommended for such applications because of their airlike characteristic impedance. Elastomers and amorphous polymers are frequently used.

To address engineering issues in acoustics especially in sound absorption problems, a metamaterial has been introduced. The use of these materials breathes new life into the classic problem of sound absorption. Materials that have been artificially structured to have qualities that are not found in natural materials are known as metamaterials (Coulais et al., 2017; Page, 2011). Metamaterials are frequently constructed up of a number of identical elements consisting of common materials such as metals or nonconductive materials. Acoustic metamaterials bring new insights because they make it easier to figure out broad working bands, low-frequency absorption, and high absorption with thin thickness. Metamaterial, which has advanced in sound absorption, has the potential to serve as next-generation sound-absorbing materials in the future, absorbing and recycling acoustic energy.

The objective of this research is to study at the sound absorption performance of AM acoustic material, which is a metamaterial, in analysis to define which acoustic material has the best sound absorption properties. Only a few studies have been published because AM research is still in its early phases, with most of them concentrating on the underlying principles and mechanics, as well as new or exciting applications. When it comes to AM sound absorption, there are only a few reviews that are significant. Thus, it has been the motivation of this work to study the sound absorption performances of AM acoustic material thru simulation. To study the sound absorption performance of Acoustic materials, mathematical analyses and virtual simulations may be used.

1.1 Problem Statement

The world's noise problem has lately become worse as a result of population growth. One of the most hazardous forms of pollution is noise, an unpleasant sound. Noise pollution in urban regions is mainly caused by the development of existing industrial operations and modes of transportation such as aeroplanes, trains, trucks, and buses. In addition, everyday human activities contribute significantly to noise levels that can be annoying to others. Noise reduction is essential for creating an acoustically pleasant atmosphere when it comes to environmental considerations. Although noise cannot be completely eradicated, it can be lowered to a level that is tolerable to the human ear. When using acoustic materials to regulate the transmission channel, sound absorbing materials limit the noise control possibilities (Kidner and Hansen, 2008). Sound absorbent material reduces noise levels by transforming sound waves into heat inside an area. Sound-absorbing materials are currently on the market and exist in various colours, shapes, and sizes.

As a result of this challenge, the researcher and developer produced metamaterial, a sound absorption substance. These materials perform well in terms of acoustics. Acoustic metamaterials have been developed in a variety of ways. Unfortunately, data are scarce on metamaterials' sound absorption and acoustical properties. As a result, more significant research into the sound absorption performance of Acoustic Metamaterials is required.

1.2 Research Objectives

The goal of this investigation is to determine how well AM Acoustic Material absorbs sound. Several objectives have been identified in order to meet this objective:

1. To determine which material that have suitable acoustical properties to be design as acoustic metamaterial for sound absorption.
2. To obtain the sound absorption coefficient of the Acoustic Metamaterial and investigate which have best sound absorption performances.

1.3 Scope Of Works

In order to meet the project's objectives and completion, the following scope of work is planned: perform experiment and simulation of sound absorption performance of AM acoustic materials.

1. Preliminary Literature Review

Literature reviews are conducted to gain background knowledge in fundamentals of acoustics, characteristics of the sound absorptive materials, metamaterials sound acoustic, and any relevant fields. This information will be gathered from a variety of sources, including local and international research papers, textbooks, lecture notes, and eBooks. Previous research or studies that are relevant to this project and whose findings are valuable in assisting in the completion of the project will be given top priority.

2. Design of Simulation Model.

The model will be designed using SOLIDWORKS software to simulate the acoustic behaviors of various configurations and materials. The model's measurements will be in MMGS format. The model will be built up according to ISO 11691:2009.

3. Simulation of Different Materials

Several key configurations are taken into account in this research in order to obtain the sound absorption performance of the materials and verify the engineering theories of acoustics used, including aspects of the material arrangement, composition, and amount of material used in the experiment/simulation. The experiment will be conducted using a variety of materials which mainly are acoustic Metamaterial in the acoustic laboratory or by simulation using COMSOL software, in order to identify the relationship between the various configurations of the materials and sound absorption performance.

4. Documentation and Presentation

The research will be documented in the form of a report, and a presentation on the research and its findings will be conducted.

1.4 Research methodology

1.4.0 Study of an existing system and literature review.

Study of an existing system and literature review is needed in this project to strengthen the fundamental of this research. Appropriate methodology, data sources, and analytical approaches can be used in this project by assessing the strengths and limitations of an existing system.

1.4.1 Metamaterial selection and preparation.

Material selection and preparation is crucial for this project because it needed to choose a material property that suitable to use in sound absorption.

1.4.2 Simulation analysis and data collection.

The simulation which is sound absorption performance of AM acoustic material assessed based on Sound Absorption Coefficient, α of each Materials. Collection of Data will be recorded throughout the simulation analysis process to determine the sound absorption performance of AM acoustic materials.

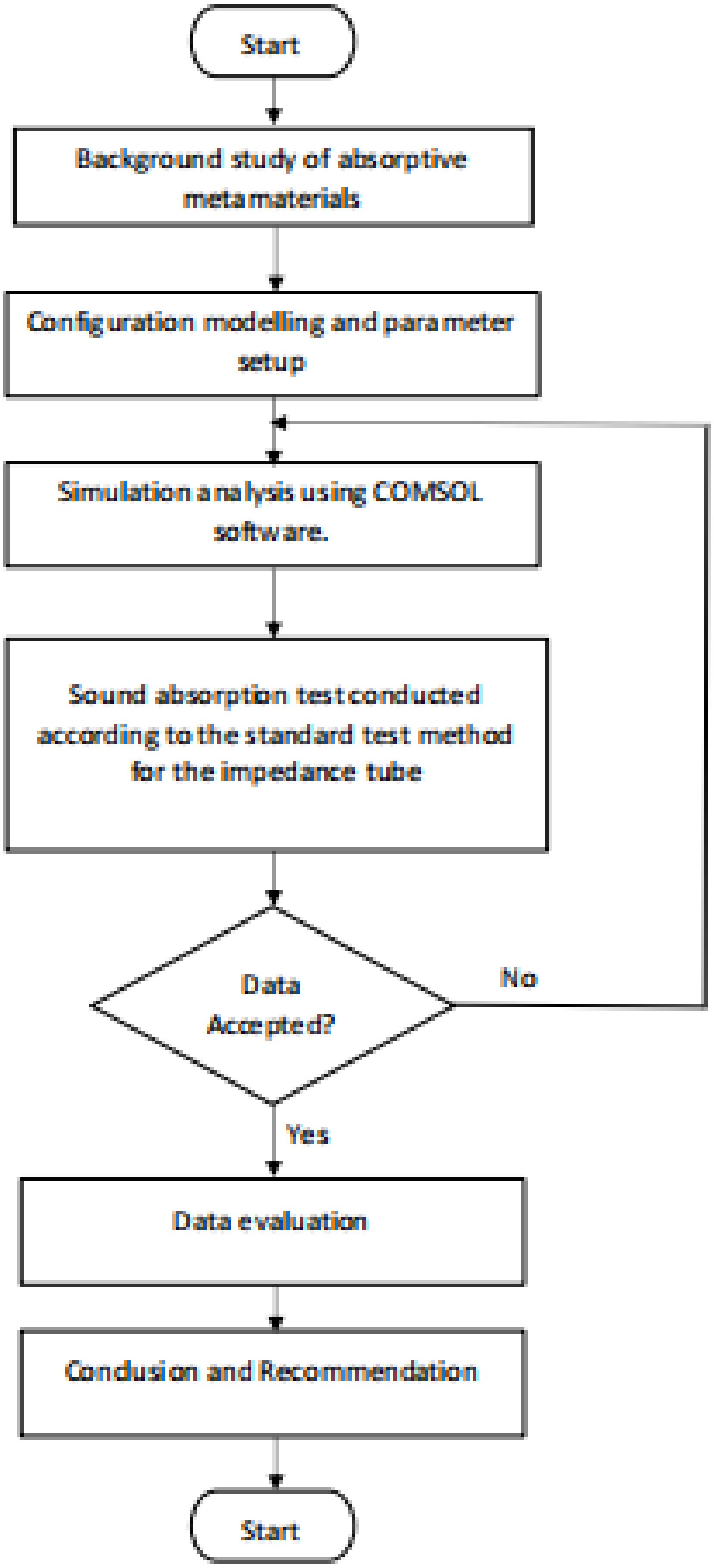


Figure 1.2: The project flow chart

1.5 Research Expected Outcomes

This research is expected to be able to perform a simulation of sound absorption performances of AM acoustic materials to compare the sound absorption coefficient of each metamaterial. Other than that, the properties of the metamaterials are another expected outcome for this study.

1.6 Research Contributions

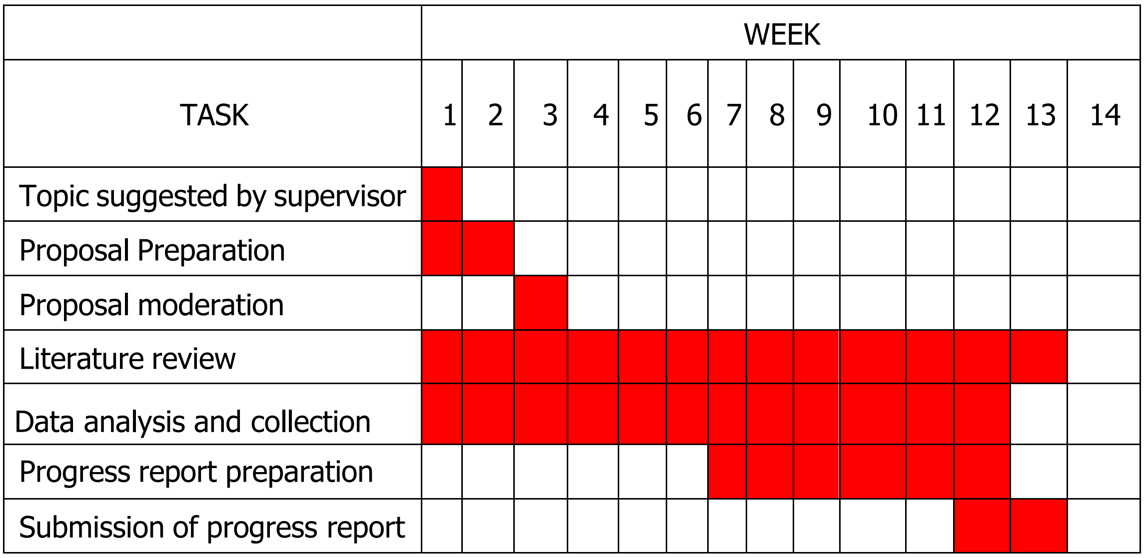
This project contributes to the simulation analysis of sound absorption performance of AM acoustic materials. The outcome of this project will profit the modern industries, specifically construction industries, manufacturing industries, and automotive because this project can act as an alternative sound absorption acoustic material as this project contributes to sustainability and performance of metamaterial sound absorption.

1.7 Research Commercialization

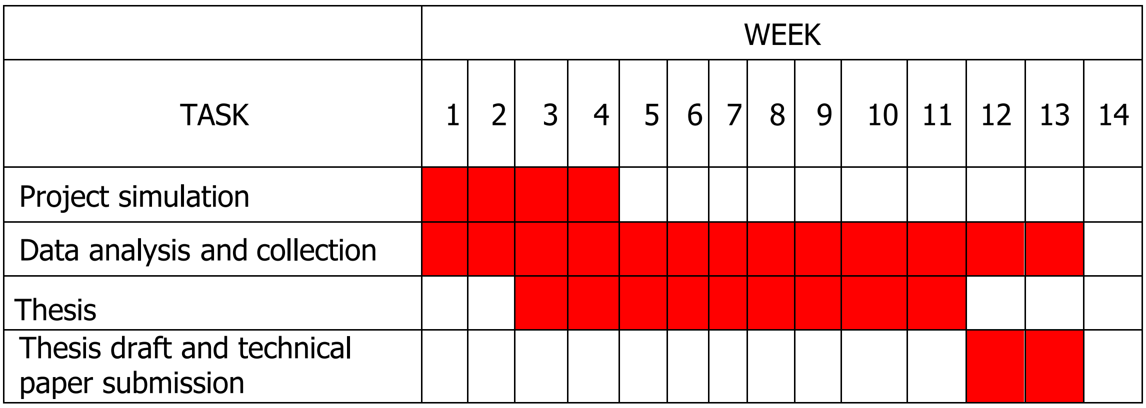
The goal of commercialization is to make a profit from this research effort. Many modern industries will benefit from the outcome of this initiative. Technological innovations have boosted the usage of acoustic Metamaterial in industrial, automotive, construction, and other applications, with a focus on sound absorption sustainability and performance. Furthermore, as people's awareness of environmental issues rises, this product will draw interest in the industry, making it possible to enter the market in the future.

1.8 Research Gantt Chart

SEMESTER 1 (2021/2022)



SEMESTER 2 (2021/2022)



CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In a literature review, new knowledge in a particular topic is discussed. While a review of materials in a specific subject may be necessary, a critical approach to evaluation is more often required, showing the links between the numerous texts and how they relate to our work. A good review of the literature will look at the research done and synthesize specific parts relevant to the selected work's theme. In simpler terms, reading a summary of literature provides readers with a thorough overview of a subject's research. Several previous investigations are examined in this chapter to establish a number of parameters needed in simulations, such as the mechanical and acoustical properties of the materials to be applied. Several terminologies, as well as the software used to conduct the simulations for this study, are also analyzed.

Acoustics is a discipline of science that investigates the generation, transmission, and effects of sound. A wave is formed when a vibrating surface causes pressure fluctuations in an elastic material (Hansen, 2004). The greater the number of sounds waves a substance can transmit, the more flexible it is. Steel is an excellent example since it is both springy and a good sound conductor. Sound travels at a certain speed through the air, water, and building materials, which is 344 m/s in the air.

When dealing with acoustics issues, frequency and wavelength are two critical elements to consider. The number of waves that occur per second is measured in hertz, representing the symbol f. The wavelength is the total distance waves travel during a single wave cycle. These two numbers indicate pressure changes in a medium that the brain interprets as sound. Human ears can perceive noises with frequencies ranging from 20 to 20,000 Hz, with the 500 Hz to 4000 Hz range being the most sensitive. The wavelength and frequency connection is inverse. They are linked by the velocity of sound, v, which displays the direction and time it takes for sound to reach listeners. As the frequency falls, the wavelength lengthens.

Furthermore, sound waves have amplitude properties that are measured in decibels and regulate how far waves go above and below the static pressure of the elastic material they are propagating through (dB). The decibel level is a measurement of a sound's loudness, the greater the decibel level, the louder the sound. A jet plane, for example, has a 140dB amplitude, but a human whisper has just 20dB. In a modern office, sound loudness varies from 40 to 60 dB. The human ear considers sound levels exceeding 65 decibels to be noise (Crocker, 1998).

One of the most unpleasant aspects that degrades human life quality is noise, or unwanted sound. Noise control is essential for creating a peaceful acoustic environment. To produce a pleasant environment, noise should be minimized to an adequate level for human hearing. The simplest method for controlling noise transmission is to place acoustical material between the source and the receiver (Arenas and Crocker, 2010). Noise isolation, noise absorption, vibration isolation, and vibration damping are the four fundamental concepts for minimizing noise in the propagation medium. The source of the noise determines it. A barrier must insulate the noise if it is airborne and comes from a loud environment. Vibration isolation or vibration dampening should be employed if the noise is produced by structure vibration and is airborne. Absorption treatment is required if the noise is generated within the room, such as echoes and reverberations. The unpleasant effects of sound reflection by hard, rigid, and interior surfaces inside a room are referred to as reverberation. The echoes are unique long-delayed reflections of the original sound that repeat it. Sound absorption therapy is an effective strategy (Long, 2006).

2.1 Sound Absorptive Materials

Sound absorbing materials function as a passive medium, converting sound to heat. It is often utilized in any industrial process to lower noise levels (Sagartzazu et al., 2008). Three types of sound absorption materials are often employed to reduce noise: membrane resonator, Helmholtz resonator, and porous absorber.

Membrane Resonators are usually solid, non-porous, stiff, or perforated with a cavity at the back. The sound reverberates off thin wood paneling over a base, lightweight substantial ceilings and floors, and other huge surfaces. It's typically used in rooms meant to reduce a specific low-frequency noise problem, such as music rooms, to counterbalance natural high-frequency absorption.

Helmholtz Resonators are similar to bottles in that they feature a sealed air volume that is linked to the room through a tiny aperture (Xu et al., 2010). Helmholtz resonators are frequently used at lower frequencies to provide adequate noise absorption (Kim and Kim, 2004).

A lot of people utilize porous absorbers (Chao and Jiunn, 2001). The bulk of porous absorbers on the market are made of fibrous media. Fibrous material is a composite medium in which fibers are suspended in air and held together by binding forces (Sides et al., 1971). Porous absorbers include foams, textiles, carpets, and cushions. These are frequently made of cellulose or mineral fibers, which are good sound absorbers and fire retardants.

For various frequencies, different absorbers have varied sound absorption properties. Each absorber's sound absorption qualities are shown in Figure 2.1. Low to mid-range frequencies are best absorbed by membrane resonators. Helmholtz resonators are effective at lower frequencies, but their frequency range is limited. Porous absorbers are efficient in absorbing liquids (Cox and Antonio, 2004). As a result, when sound absorption treatment is needed to solve a noise problem in a space, the material used must be suitable for the frequency range in question.