SIMULATION STUDIES ON TRANSMISSION LOSS OF ACOUSTIC MATERIALS

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DECLARATION

I hereby declare that this thesis, submitted to University Malaysia Sabah as a partial fulfilment of the requirement for the degree of Bachelor of Mechanical Engineering, has not been submitted to any other university for a degree. I also certify that the work described herein is entirely my own, except for quotations and summaries of sources which have been duly acknowledged.

15TH January 2022

MUHAMMAD SAZALEE BIN SAIFUDIN

CERTIFIED BY

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ABSTRACT

In the current state of world where technology has advances on daily basis has introduced a new set of problems to the urban community which is sound itself especially in a high population density area. This leads to noise pollution, namely sound transmission loss to be precise. According to the World Health Organisation (WHO) Noise pollution is considered to be the third most hazardous pollution after air and water pollution. Sound can be a double-edged sword as it has a tremendous amount of benefit that also brings its own caveat. It has been a constant battle to improve transmission loss in that sector in order to reduce the noise pollution especially in the building sector as its where most people will be working and doing everyday tasks. In this research, it will be focused towards simulation studies on transmission loss towards acoustic materials. The simulation will be conducted by using COMSOL Multiphysics using the features in it to assist on determining the transmission loss which is pressure acoustics and frequency domain. The setup for the simulation will involve the acoustical metamaterial structure of single-layer sandwich metamaterial plate and modelled of reverberation chamber based on standard ASTM E90. Aluminium will be the host plate which is the controlled variable, whereas melamine foam, polyurethane foam and glass fibre will be the surface plate. A total of three different thickness will be tested at different frequency level from 100 Hz until 5000 Hz; 30mm, 60mm and 90mmm for surface plate, with a constant thickness of host plate, 20mm. Result shows that the 90mm thickness has a superior performance in transmission loss for low frequency range between 100 Hz and 1600 Hz. In the higher frequency range from 1600 Hz to 5000 Hz 30mm thickness has higher transmission loss. Material also proven to play a vital role in the result as glass fibre with the highest density material has a higher transmission loss compared to melamine foam and polyurethane foam with lower density.

ABSTRAK

Kajian Simulasi Mengenai Kehilangan Transmisi dalam Bahan Akustik.

Dalam keadaan dunia semasa di mana teknologi mempunyai kemajuan setiap hari telah memperkenalkan satu kumpulan masalah baru kepada masyarakat bandar yang sihat itu sendiri terutamanya di kawasan kepadatan penduduk yang tinggi. Ini membawa kepada pencemaran bunyi, iaitu kehilangan penghantaran bunyi secara tepat. Menurut Pertubuhan Kesihatan Sedunia (WHO) Pencemaran bunyi dianggap sebagai pencemaran ketiga paling berbahaya selepas pencemaran udara dan air. Bunyi boleh menjadi kebaikan dan keburukan dalam masa yang sama kerana ia mempunyai manfaat yang besar dan juga membawa kaveatnya sendiri. Ia telah menjadi perjuangan berterusan untuk meningkatkan kehilangan transmisi dalam sektor itu sekaligus mengurangkan pencemaran bunyi terutamanya dalam sektor bangunan kerana kebanyakan orang akan bekerja dan melakukan tugas harian. Dalam penyelidikan ini, ia akan ditumpukan kepada kajian simulasi mengenai kehilangan transmisi terhadap bahan akustik. Simulasi akan dijalankan dengan menggunakan COMSOL Multiphysics dengan ciri-ciri di dalamnya untuk membantu dalam menentukan kehilangan transmisi iaitu tekanan akustik dan domain frekuensi. Persediaan untuk simulasi akan melibatkasn struktur metamaterial akustik plat metamaterial sandwic satu lapisan dan dimodelkan ruang gema berdasarkan standard ASTM E90. Aluminium akan menjadi plat perumah yang merupakan pembolehubah terkawal, manakala buih melamin, buih poliuretana dan gentian kaca akan menjadi plat sandwic/bahan. Sebanyak tiga ketebalan berbeza akan diuji pada tahap frekuensi berbeza dari 100 Hz hingga 5000 Hz; 30mm, 60mm dan 90mmm untuk plat bahan, dengan ketebalan tetap plat hos, 20mm. Keputusan menunjukkan bahawa ketebalan 90mm mempunyai prestasi unggul dalam kehilangan penghantaran untuk julat frekuensi rendah antara 100 Hz dan 1600 Hz. Dalam julat frekuensi yang lebih tinggi dari 1600 Hz hingga 5000 Hz 30mm ketebalan mempunyai kehilangan penghantaran yang lebih tinggi. Bahan juga terbukti memainkan peranan penting dalam hasil kerana gentian kaca dengan bahan ketumpatan tertinggi mempunyai kehilangan penghantaran yang lebih tinggi berbanding dengan buih melamin dan buih poliuretana dengan ketumpatan yang lebih rendah.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

According to Eveleth (2016), the first ever sound that was recorded was gathered by a device called a phonautograph. The Phonautographs transcribe the sound waves into a line that will be drawn on a paper or a glass. It was invented by a man named Édouard-Léon Scott de Martinville in 1857. This discovery has led to the advancement technological status of sound's invention that has push the nature of sound to a whole different spectrum. To understand sound in depth, understanding the meaning of it is crucial.

Sound is a mechanical disturbance from a state of equilibrium that propagates through an elastic material medium. A purely subjective definition of sound is also possible, as that which is perceived by the ear, but such a definition is not particularly illuminating and is unduly restrictive, for it is useful to speak of sounds that cannot be heard by the human ear (Richard E. Berg, 1998)

To apprehend the complex nature of sound itself, there is a lot of phenomena that co-exist with the presence of sound such as sound absorption and transmission loss. In this project, we will be focusing on STL. STL is a quantification of how much sound energy is prevented from travelling through an acoustic treatment. Transmission loss quantifies the effectiveness of acoustic treatments for an engineering application. It can also be defined as a ratio of the sound energy transmitted through a treatment versus the amount of sound energy on the incident side of the material (Siemens, 2019). The material that will be focused on is acoustic metamaterial (AMs).

Acoustic is the study of the creation, control, transmission, reception, and effects of sound. The word comes from the Greek word akoustos, which means "heard" (Berg, Richard E.,2019). AMs can be achieved with the using the metamaterial itself. Metamaterials are metal-dielectric composites structed on the microscale or nanoscale. For electromagnetic waves with relatively large wavelengths, the composite structure acts as an array of artificial atoms giving rise to unique and exotic electromagnetic properties. To put it simply, it is a material that could not be found in nature and is formed with the thought of design towards the needs and functionality of the material.

In regard to acoustic, noise is something that could not be elude from as it is a by-product of sound itself. Noise in acoustic can be defined as any unwelcome sound, whether it is innately undesirable or interferes with listening to the other sounds. In electronics and information theory, it refers to unpredictable, and undesired signals, or changes in signals, that obscure the desired information content.

In addition, as the world advances noise pollution has become a real threat to our society. Noise pollution can be categorised as unwanted or excessive sound can have negative consequences for human health, wildlife, and the environment. Noise pollution is frequent in many industrial buildings and other workplaces, but it also occurs as a result of highway, train, and aviation traffic, as well as outdoor construction operations.

According to Yuen FK (2014), urbanization, industrialization, rapid housing expansions, population increase, and technology advancements have all been linked to noise pollution. Through a variety of methods, environmental noise disrupts social behaviour and manifests as psychological and physiological diseases. Continuous noise exposure of 85-90 dBA may cause progressive hearing loss and alterations in threshold sensitivity. The volume, diversity, and severity of these discomfort reactions are related to the everyday activities.

Thus, the project is focused on studying the transmission loss on acoustic materials by simulation. It is centralized on the use of AMs on building walls/panel to improve the transmission loss of sound.

1.2 Problem Statement

The continuous growth of our society structure has introduced a new set of problems to the urban community which is sound itself especially in a high population density area. As technology advances, job opportunities will indefinitely increase which in turn created this everlasting request and need for housing placement. Thus, the start of urban housing structure or high construction volume that is design focused on essentials rather than comfortability. For example, wall design using thin walls and cheap insulation material to maximize space usage and to increase the total of people residing in the building.

The problem that occurs with this is noise pollution, STL to be more specific. According to the World Health Organisation (WHO) Noise pollution is considered to be the third most hazardous pollution after air and water pollution. Short as well as long-term exposure to noise pollution has a variety of negative impacts on humans, including psychiatric illnesses including anxiety and depression, hypertension, hormone malfunction, and blood pressure rises that contribute to cardiovascular disease (Basu et al., 2021).

Furthermore, without the proper usage of material for the wall insulation, the amount of transmission loss will decrease which can be unpleasant for the neighbours and people that are near it. The slightest of sound can penetrate the wall if proper design is not executed. By using the correct AMs for the wall, the problem itself would not exist in the first place. In addition, choosing the suitable AMs is already an issue itself as designing and creating it can be problematic. With the suitable material and metamaterial structure, the sound absorb by it can inevitably improve the STL.

Thus, the project purpose is to studies the sound transmission loss performance on acoustic material by performing proper simulation. The research will be mainly focus on STL performance of acoustic metamaterial with different configuration for sound insulation in building wall/panel.

1.3 Research Objectives

The main objective for this research is to investigate and study sound transmission loss performance on acoustic metamaterial. The main objective can further be specified into sub-objectives as the following:

1. To determine the most effective acoustic metamaterial configuration to improve sound transmission loss.
2. To compare the sound transmission loss performance of acoustic metamaterials at different frequency level.

1.4 Scope of Works

The project scope of work is listed as following to achieve the research objectives of the project which is simulation studies on transmission loss of acoustic material.

1.4.1 Preliminary Literature Review

Conducting background research on previous studies on transmission loss studies on acoustic material gain more knowledge on the project. The findings will be used as reference to further improve the studies. A total of 20 article will be the minimum for the literature review to be conducted on.

1.4.2 Selection of Acoustic Material

The acoustic material will be chosen based on metamaterial that are suitable to be used for building wall/panel insulation. A total of three different AMs with three different level of density will be tested on. The result will then be compared to determine the suitable AMs to solve the problem statement.

1.4.3 Simulation of the Project.

The simulation will be carried out using COMSOL Multiphysics for design configuration, mathematical modelling and simulate the project accordingly. It will follow standard ASTM E90. The STL will be studied by comparing the STL of each AMs in different frequency. The AMs will also be tested in different configurations to further understand the transmission loss performance. The configurations include different level of thickness.

1.4.4 Finite Element Method (COMSOL Multiphysics)

For the simulation method, COMSOL Multiphysics will be used to simulate the project and obtained the estimated data. The noise frequencies ranges from 100 Hz to 5000 Hz. The software will also be used to study the AMs behaviour and characteristics based on the properties set in the simulation. The parameters set includes pressure acoustics and frequency domain.

1.4.5 Project Documentation

The research will be documented in the form of report and presentation with regards on the project findings and research outcome. Results will be tabulated and graph according to the correct format. The results will also be compared with past research to analyse and validate the obtained data.

1.5 Research Methodology

The project will focus simulation using COMSOL Multiphysics. The data gathered from the study of transmission loss on AMs will be compared and analyse to determine the most effective configurations.

1.5.1 Literature Review

Conducting literature review and background research to further the understanding of the project to help on achieving the objectives. The research paper and journal will be chosen based on its credibility towards the project. The literature review will cover the topic of sound transmission loss, sound absorption, sound insulation, acoustic material, noise pollution, etc.

1.5.2 Acoustic Material Selection

The material selection will be based on material that are commonly used light acoustic absorbing material that are used for wall insulation in buildings. The selection process itself is important for the project as it will determine the data gathered and analysis of the STL. The criteria that will be focused on are the density level of material, ranges from low, medium to high.

1.5.3 Data Gathering and Analysis

The simulation is conducted to observe the effect of STL towards different AMs by COMSOL Multiphysics only. In this project, the AMs used will be Glass Fibre, Polyurethane Foam and Melamine Foam. The data that needs to be gathered is the STL of each AMs at different frequency. The data will then be discussed and analyse according to the research objectives to determine whether it is achieved or not.

1.5.4 Result Validation

Simulation using COMSOL Multiphysics will be validated by comparing the obtained data with the previous research paper regarding the same topic as the project.

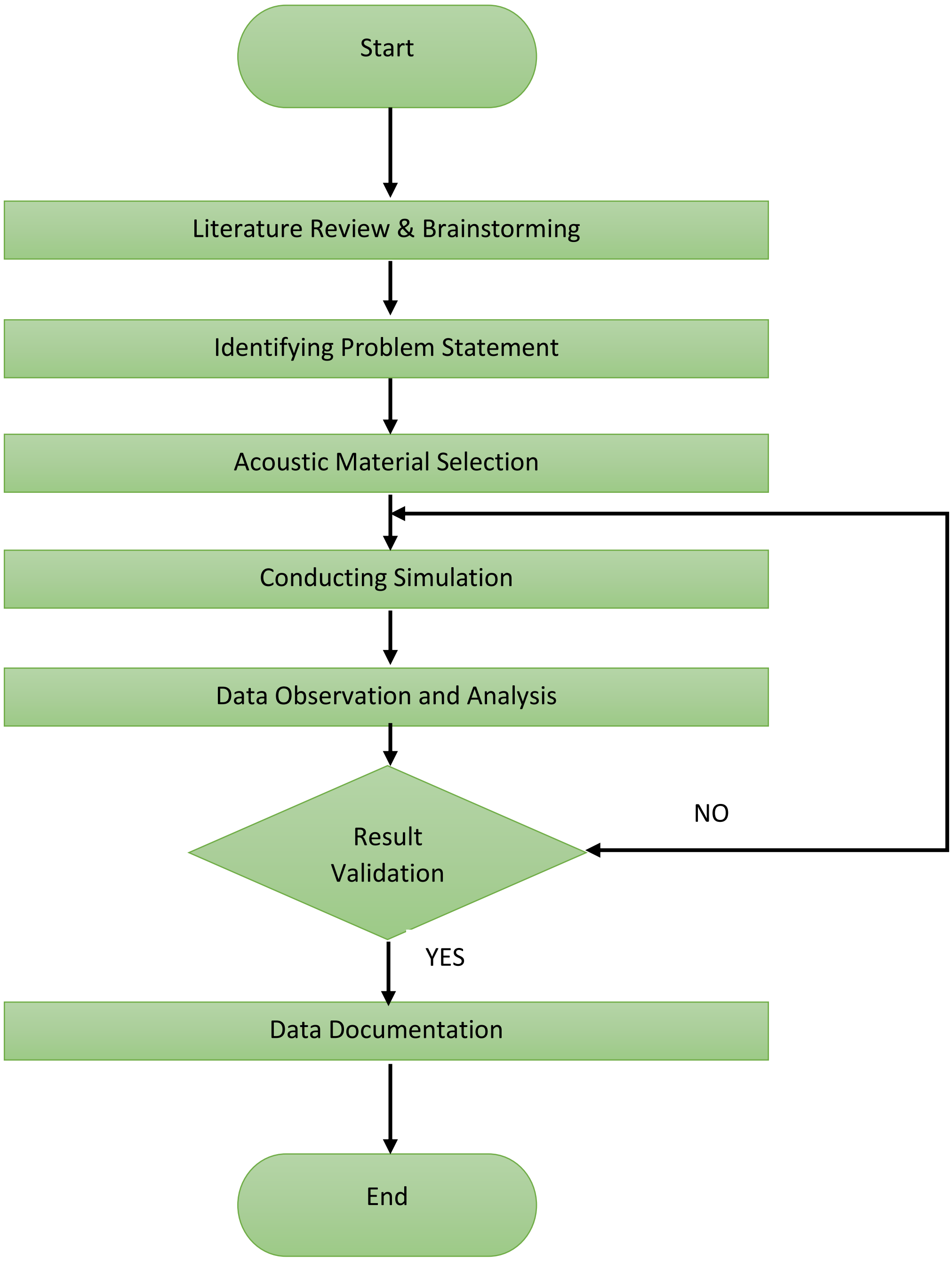

Figure 1.1: Project flow chart for the methodology.

1.6 Research Expected Outcomes

The research expected outcomes for this particular project is to be able to carry out simulation studies on transmission loss of acoustic materials whilst comparing the transmission loss of chosen materials with different thickness. Besides that, to study the characteristics of the acoustic metamaterial structure with different configuration in depth.

1.7 Research Contribution

The project research is aimed to contribute to the studies of simulation of transmission loss in acoustic material. It will benefit mainly construction company as the project is focused on the studies on transmission loss effect on building wall insulation. It can also improve on the studies towards the understanding of metamaterial for acoustic purposes.

1.8 Research Commercialization

The project can be utilized by construction company in high density population area such as main urban city that requires suitable housing with comfortability of sound as the main criteria to be dealt with. The data gathered from the project can help innovate and improve the sustainability of AMs for STL in multiple sectors such as construction and automotive.