UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND FABRICATE ABSORPTIVE MUFFLER TO ANALYSE SOUND TRANSMISSION LOSS BASED ON JUTE FIBRE USING IMPEDANCE TUBE

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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 And Fabricate Absorptive Muffler To Analyse Sound Transmission Loss Based On Jute Fibre 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 : Sritaran

Name : Sritaran A/L Arumugam

Date : 17/1/2022

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 : 27/1/2022

DEDICATION

I would like to acknowledge and thank my Project Supervisor, Ts. Muhammad Nur Bin Othman, for his guidance. As an expert in mechanical systems theory and practice, his advice was invaluable and contributed extensively to the learning experience and also have been guiding me to finish this project successfully. Finally, my deepest appreciation will go to my friends, their patience, understanding, and flexibility throughout this undertaking has been admirable.

ABSTRACT

Noise from automotive is still an issue that has negative effects on the environment and human health. The absorptive muffler, which is applied using sound-absorbing material made of synthetic fibre, is still being used widely. The use of synthetic fibre as a sound absorbing material in absorptive mufflers has a significant impact on human health and is harmful to the environment. In this research, an absorptive muffler was used to analyse the sound transmission loss using jute fibre. Jute fibre is a natural fibre that is fully biodegradable which are widespread and affordable were used as the absorptive material for this research. The goal of this project is to design an absorptive muffler using SolidWorks software and fabricate it using FDM 3D printer. Then, the constructed absorptive muffler is used to analyse the sound transmission loss of jute fibre's absorptive muffler using impedance tube. An absorptive muffler was designed by using SolidWorks software and then the design was transferred into 3D printer in numerical format. Polylactic acid (PLA) was used as a material to fabricate the absorptive material. Once done with the fabrication, jute fibre will be placed inside the absorptive muffler and started to analyse the sound transmission loss using impedance tube. In addition, for this study, 8 different types of samples with two different thicknesses were used in absorptive muffler. As an outcome, a circular absorptive muffler was successfully designed and fabricated using a 3D printer. The highest sound transmission loss measured in this research was 26.44dB at 5000Hz for a 14cm length jute fibre. This project is expected to initiate the use of natural fibre as a better replacement for synthetic fibre as a sound absorptive material in absorptive muffler and hopefully this will be a good approach by the muffler industry in the near future.

ABSTRAK

Bunyi bising dari automotif masih menjadi masalah yang memberi kesan negatif terhadap alam sekitar dan kesihatan manusia. Peredam penyerapan, yang digunakan menggunakan bahan penyerap bunyi yang diperbuat daripada serat sintetik, masih digunakan secara meluas. Penggunaan serat sintetik sebagai bahan menyerap bunyi dalam peredam penyerapan mempunyai kesan yang signifikan terhadap kesihatan manusia dan berbahaya kepada alam sekitar. Dalam kajian ini, peredam penyerapan akan digunakan untuk menganalisis kehilangan penghantaran bunyi menggunakan serat jute. Serat jute adalah serat semulajadi yang sepenuhnya terbiodegradasi yang meluas dan berpatutan digunakan sebagai bahan penyerapan untuk kajian ini. Matlamat projek ini adalah untuk merekabentuk peredam penyerapan menggunakan perisian SolidWorks dan mengarangnya menggunakan pencetak FDM 3D. Kemudian, peredam penyerapan yang dibina digunakan untuk menganalisis kehilangan penghantaran bunyi peredam penyerapan serat jute menggunakan tiub impedans. Peredam penyerapan direka dengan menggunakan perisian SolidWorks dan kemudian reka bentuk telah dipindahkan ke pencetak 3D dalam format berangka. Asid polylactic (PLA) digunakan sebagai bahan untuk mengarang bahan penyerapan. Sebaik sahaja dilakukan dengan fabrikasi, serat jute akan diletakkan di dalam peredam penyerapan dan mula menganalisis kehilangan penghantaran bunyi menggunakan tiub impedans. Di samping itu, untuk kajian ini, 8 jenis sampel yang berbeza dengan dua ketebalan yang berbeza digunakan dalam peredam yang diserap. Sebagai hasil, muffler penyerapan pekeliling telah berjaya direka dengan menggunakan pencetak 3D. Kehilangan penghantaran bunyi tertinggi yang diukur dalam kajian ini adalah 26.44dB pada 5000Hz untuk serat jute yang panjang 14cm. Projek ini dijangka memulakan penggunaan serat semulajadi sebagai pengganti yang lebih baik untuk serat sintetik sebagai bahan penyerapan bunyi dalam peredam penyerapan dan diharapkan ini akan menjadi pendekatan yang baik oleh industri peredam dalam masa terdekat.

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LIST OF SYMBOLS AND ABBREVIATIONS

FDM	-	Fused Deposition Modeling
3D	-	Three dimension
HVAC	-	Heating, Ventilation and Air Conditioning
Hz	-	Hertz
TL	-	Transmission Loss
dB	-	Decibel
SEM	-	Scanning Electron Microscope
PLA	-	Poly Lactic Acid
STL	-	Stereolithography

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Noise is defined as any undesired sound that is regarded unpleasant, loud, or disturbing to hearing. From the perspective of physics, vibrations across a medium, such as air or water, noise and intended sound are both identical. Noise can be caused by a variety of factors such as car's running engine, noise from road traffic, noise from machines and so on. Long-term or severe noise subjection has been linked to a variety of health issues such as hearing loss, sleeping difficulty, high blood pressure and stress. These health issues can impact people of all ages, but notably children.

Noise from automotive has a number of negative effects on human health. Throughout the years, mufflers are commonly utilized to minimize flow noise inside a duct, such as in a car exhaust system or a household appliance ventilation system. The absorptive muffler is built up of ducts and chambers lined with sound absorption materials (Kalita et al., 2014). In absorptive muffler, sound is largely attenuated by absorbing sound energy. Mostly, synthetic fibres were used in absorptive muffler like glass wool and fiberglass as sound absorption material. The synthetic fibre have some drawbacks like contributing to global warming and causes significant health risks to humans such as cause lung infection and skin irritation.

In this study, absorptive muffler will be made using 3D printer. Poly Lactic Acid (PLA) will be used to make the absorptive muffler, which will be lighter in weight. Jute fibre is utilized as a substitute for synthetic fibre since it has several advantages such as being entirely biodegradable, recyclable, and environmentally friendly (Aly-Hassan, 2015). In this

study, the impedance tube method will be employed to analyse sound transmission loss. In general, transmission loss defines the accumulated drop in intensity of a waveform's energy as it propagates outwards from a source.

1.2 Problem Statement

The utmost intent of this research is to design and fabricate an absorptive muffler using FDM 3D printer. The noise produced by the absorptive muffler has been an issue, and the synthetic fibre used in the absorptive muffler can cause a variety of problems for humans and the environment. Glass wool, fibreglass, and other popular sound-absorbing materials are used in the market. However, fibreglass as a sound-absorbing material creates a serious health risk to people due to fibreglass shedding, which can cause lung infection, skin irritation, and eye irritation. Besides, synthetic fibres also known as manufactured fibres, it also specially harmful to the environment such as non-biodegradable, long time to breakdown and resulting in long-term contamination. As an outcome, the focus of this project was on natural fibre in order to determine its acoustical performance in an absorptive muffler prototype.

1.3 Objective

The objective of this research are:

i. To design the absorptive muffler using SolidWork software.

ii. To fabricate the absorptive muffler using FDM 3D printer.

iii. To analyse the sound transmission loss of jute fibre's absorptive muffler using impedance tube.

1.4 Scope of Research

The project began with the goal of developing an absorptive muffler made of thermoplastic which is polylactic acid (PLA) and replacing synthetic fibre with natural fibre which is jute fibre as a sound absorption material. The goal of this project is to design and fabricate an absorptive muffler using SolidWork software and FDM 3D printer. Then, the constructed absorptive muffler will be used to analyse the sound transmission loss of jute fibre's muffler by utilizing impedance tube. The first breakdown work required to finish this project is to design the absorptive muffler using SolidWork software. Second, the FDM 3D printer will be used to fabricate the absorptive muffler. Then, the placement of jute fibre inside the absorptive muffler. The test for the analysis will be performed when the construction of the absorptive muffler and the placement of jute fibre are completed. The sound transmission loss will be measured in this study. The dimension and thickness of the jute fibre are the project's control parameter. The schedule to complete the project during the pandemic was a constraint in this project. The exhaust heat will not be included in this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Studies on Noise Pollution and its impact towards human

Noise is described as any sound that exceeds the allowable, unacceptable, and alarming limit and causes serious harm to human health (Hadi Hassan Al-Taai, 2021). Noise is an unwanted sound because it causes physiological and psychological damage to an organism for a small or long period. An auditory sound received by a human being as feedback to the body is referred to as noise. Amares et al. (2017) stated that noise is clearly linked to the annoyance experienced by humans as a result of the machines and equipment used in everyday activities. Noise is described as an unwelcome or unexpected sound (Bahl et al., 2020). Noise pollution is caused by various noise sources such as white noise, pink noise, coloured noise, recreational noise, road traffic noise, truck noise, building noise, machinery noise, aircraft noise, and so on. Aluko and Nna (2014) mentioned that one of the man-made environmental threats that receives the least consideration is noise pollution. Noise pollution, as described by the World Health Organization (WHO), is unwelcome or excessive sound that can have a negative impact on human health and environmental quality.

There are several sources of noise pollution. Aluko and Nna (2014) stated that industrial equipment and operations, heavy vehicle traffic, trains, airplanes, electrical machines, public address devices, and turbines used for commercial and domestic uses are all causes of artificial noise pollution. Mining, bridge, dam, house, station, lane, and flyover development, as well as noise from social events, make the area unfriendly and possibly uninhabitable. The most disruptive and powerful noises, such as those generated by tens of thousands or hundreds of thousands of cars and jets during their ascents and landings, as

well as other modes of transportation such as trains, motorcycles, and others on city streets that do not stop at night or day, are also sources of noise pollution (Hadi Hassan Al-Taai, 2021). The amplification of radios and televisions, registration in stores, houses, and buses, the misuse of cell phones by students, the misuse of loudspeakers by itinerant sellers, and other forms of noise pollution are often included.

Bahl et al. (2020) declared continuous noise pollution might have serious consequences for public wellbeing. Noise and noise exposure have detrimental impacts on mental health of children and youth, but they remain understudied (J. Lim et al., 2018). Hadi Hassan Al-Taai (2021) mentioned that a considerable number of environmental experts and others interested in pollution have been interested in researching the effect of noise on pollution. The deeper the compression and depression waves, and therefore the more harmful they are to humans, the more violent the vibration. Noise often induces psychological and physical illness in humans because of being subjected to unexpected and distracting noisy noises, especially when exposed to them constantly, over extended periods, often from multiple source. Distress contributes to eardrum tearing by tearing the literary cells of the human ear, which are similar to haemophilus tissue. Aluko and Nna (2014) stated that the most prominent and often discussed health effect of noise is noise-induced hearing loss (NIHL), but tests have shown that exposure to continuous or elevated levels of noise can cause a number of adverse health effects. It may damage psychological health and high noise levels have been related to the development of violent activity, constant stress, and fatigue. Loud noise disrupts sleep patterns, resulting in fatigue, decreased performance, and the development of sleep disorders. Finally, in fact all this will lead to more serious and persistent health problems later in life.

2.2 Studies on Silencer

Silencers, also known as sound attenuators, absorbers, or mufflers, are devices that are used to minimize the amount of noise emitted from a source to a receiver (Bujoreanu & Benchea, 2017). As acoustic comfort standards have become stricter, noise attenuation in ventilation ducts has become a major focus in the HVAC industry. The most popular silencers used in HVAC applications are duct silencers, which are mounted on the intake and/or discharge side of a fan or air handler. Duct silencers are used to minimize noise produced by fans, air passage through straight ducts, and the effect of air passing through components such as elbows, mixing boxes, and branches (Yadav & Bahekar, 2017). Arslan et al. (2020) stated that silencers are categorized into three types: reactive, dissipative, and hybrid. Controlling noise pollution from power generation systems is typically accomplished by the use of passive noise reduction mechanisms such as reactive and dissipative sound attenuators (Williams et al., 2018). Arslan et al. (2020) explained that reactive silencers use acoustics impedance difference to produce dissipative sound waves generated by geometric discontinuity. The reactive elements are typically used to resolve low frequency noise, especially tonal noise, which is common in power generation (Williams et al., 2018).

Besides that, dissipative silencers are approved for wide frequency bands (Bujoreanu & Benchea, 2017). Dissipative silencers convert sound energy into heat energy, reducing acoustic pressure fluctuations (Arslan et al., 2020). Bujoreanu and Benchea (2017) stated that they dampen the sound, especially due to the existence of sound-absorbing materials with a certain flow resistivity. These silencers are the most often used for noise reduction in situations where fan noise, flow induced noise, and engine noise must be reduced. Duct silencers come in a variety of designs, including rectangular, oval, and elbow versions, as well as varying sizes based on the duct form. The exterior appearance of a commercial duct silencer is usually identical to that of a slice of duct. Williams et al. (2018) mentioned that

since dissipative silencer designs do not perform well at low frequencies, it is possible for larger devices to experience a drop in silencer output in the low to medium frequency range. Dissipative silencers are commonly found on their own in larger applications, such as gas turbines or fans used in heating, cooling, and air conditioning systems. Moreover, the wider ductwork reduces gas flow velocities to values low enough to enable the silencers to be mounted inside the main duct. Finally, hybrid silencers are made up of a mixture of reactive and absorptive forms (Arslan et al., 2020). Figure 2.1 below shows a baffled silencer.

Figure 2.1 A baffled silencer, Arslan et al., (2020)

2.3 Studies on Muffler

Kalita et al. (2014) explained that a muffler is a tool that reduces the level of noise generated by an internal combustion engine's exhaust. The muffler contains various components for transmission loss, such as perforated tubing, absorption materials, and so on, which minimize noise. Mufflers are also a vital part of the automotive exhaust system because they reduce the noise generated by engine combustible materials when they travel through the exhaust system (Prajapati & Desai, 2016). Inside the muffler, the pressure drop occurs as well. Mufflers are located in the exhaust system after the catalytic converter and are the last part connected to the exhaust system. A vehicle without a muffler would

appreciate the big change in noise level that a muffler will create. There would be an unbearable level of engine noise in our atmosphere if cars did not have mufflers. Next, the automobile muffler allows exhaust gases to flow through while limiting sound propagation. Mufflers are classified into two categories, which are the Reactive muffler and Absorptive muffler. Nowadays, the mixed reactive and absorptive model muffler, also known as a hybrid muffler, is widely used.

According to Alinaghi (2015) active mufflers are not yet ready for mass production. As a result, the industry is focusing on passive mufflers, which use either reflection or absorption to decrease the amount of transmitted noise. The degree of exhaust noise control is determined by the design and operation of mufflers. Over the last century, mufflers have been produced using electro-acoustic analogies and experimental trial and error. Stewart developed the basic theory and architecture of acoustic filters using electro-acoustic analogies several years ago. Davis et al. later presented the findings of a systematic review on mufflers. They used travelling wave solutions to the one-dimensional wave equation and the premise that acoustic pressure and velocity are constant as cross-sectional area varies. Figure 2.2 below depicts the application of mufflers in cars to reduce the amount of noise made by the engine.

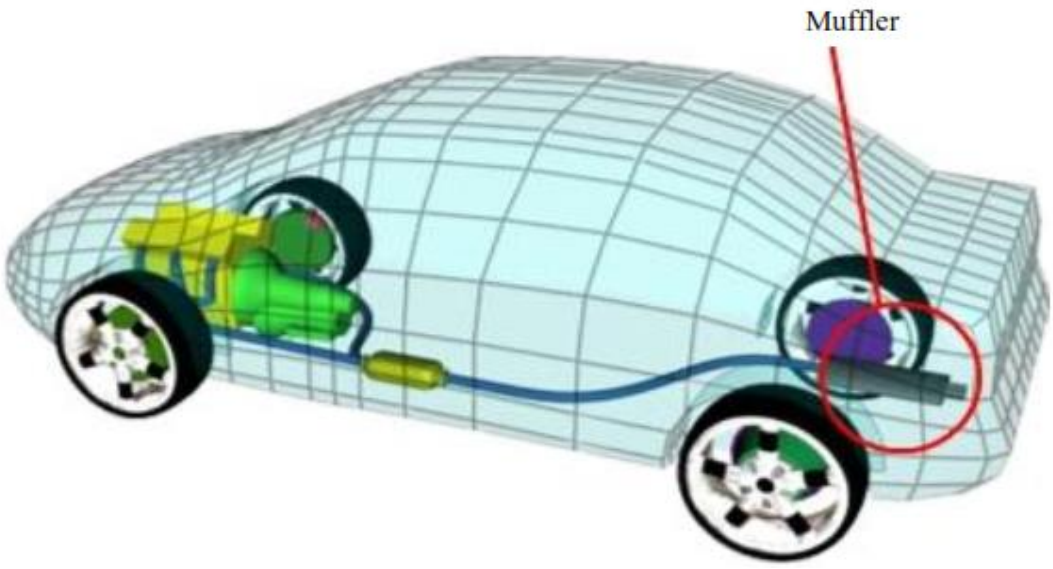

Figure 2.2 Application of muffler in cars to reduce the amount of noise made by the engine, Alinaghi (2015)

2.3.1 Studies on Reactive Muffler

Shen and Hou (2017) stated that to reduce the low-frequency noise generated by internal combustion engines, a reactive muffler is needed. On the other hand, reactive mufflers are intended to reflect the engine's sound waves, causing the sound waves to partially cancel each other out (Prasad & Thiagarajan, 2019). The theory of destructive interference refers to this phenomenon. First, within expansion chambers, the original sound waves created by engine noise are directed to create another equivalent and opposite reflected sound wave. Then, when these waves collide, they cause destructive interference, resulting in sound cancellation. The researcher has mentioned that reactive muffler is made up of multiple chambers that are linked together with tubular pipes to produce sound reflection at each junction. The impedance mismatch and reflection of the incident sound wave enable the acoustic energy to be returned to the source, reducing engine noise within the muffler. It has been discovered that noise suppression is inversely proportional to backpressure. An optimal reactive muffler can be designed by rearranging the expansion