EVALUATION OF ISOLATORS TO REDUCE VIBRATIONAL EFFECT FOR SMALL SCALE THERMOACOUSTIC SYSTEM

SYAZIRA BINTI HAMDAN

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EVALUATION OF ISOLATORS TO REDUCE VIBRATIONAL EFFECT FOR SMALL SCALE THERMOACOUSTIC SYSTEM

SYAZIRA BINTI HAMDAN

This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2021

DECLARATION

I declare that this project report entitled "Evaluation of Isolators to Reduce Vibrational Effect for Small Scale Thermoacoustic System" 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.

Signature : ....

Name of Supervisor : ....

Date : ....

DEDICATION

To my beloved mother, Rozainah Binti Ahmad and my father, Hamdan Bin Abdul Hamid

ABSTRACT

A thermoacoustic system, also known as a thermoacoustic phenomenon, is an event that allows for the conversion of energy between heat and sound. In industry, any systems and machinery are exposed to vibration. Vibrations that occur within a structure or a system are still one of the most common issues in the industrial sector. Vibrations are undesirable because they might compromise the functionality and durability of a system. This project focuses on the vibration that happens inside a small-scale thermoacoustic test rig. However, the best parameter design for a thermoacoustic test rig must be determined so that the real thermoacoustic rig will be designed and operate with a less vibrational effect. Therefore, a study to evaluate the most suitable isolators for the small-scale thermoacoustic system has been conducted in this project. The vibrational measurement has been done using an accelerometer to determine the natural frequency of the system with two conditions: a system without an isolator and a system with an isolator. Then, the theoretical calculation of the proposed isolators is done to determine the best material for the isolator based on a comparative study. From the comparative study, it is found that silicone rubber has the capability to reduce the vibrational effect up to 86.67%. In conclusion, silicone rubber is chosen as the best material for isolators to reduce the vibrational effect in the thermoacoustic system.

ABSTRAK

Sistem termoakustik, yang juga dikenali sebagai fenomena termoakustik, merupakan proses yang membolehkan proses penukaran tenaga antara haba dan bunyi. Di dalam industri, setiap sistem atau mesin pasti akan mengalami proses getaran. Getaran yang berlaku di dalam struktur atau sistem merupakan salah satu permasalahan yang paling kerap terjadi di sektor perindustrian. Getaran ini tidak diingini kerana ia boleh menjejaskan fungsi dan ketahanan sesuatu sistem. Projek ini memfokuskan pada getaran yang berlaku di dalam sistem termoakustik yang berskala kecil. Walau bagaimanapun, reka bentuk dan parameter terbaik bagi sistem termoakustik berskala kecil mestilah dikenalpasti supaya sistem termoakustik bersaiz sebenar dapat beroperasi dengan kesan getaran yang sedikit. Oleh itu, kajian untuk menilai dan menentukan isolasi getaran yang paling sesuai, untuk sistem termoakustik berskala kecil telah dilaksanakan dalam projek ini. Ukuran dan dapatan dari proses getaran telah dilakukan dengan menggunakan "accelerometer" untuk menentukan frekuensi semula jadi sistem dengan dua keadaan: sistem tanpa isolasi getaran dan sistem dengan isolasi getaran. Kemudian, pengiraan teori isolasi getaran telah dilakukan bagi menentukan bahan yang terbaik untuk isolasi berdasarkan kajian dan perbandingan. Dari dapatan kajian, didapati bahawa getah silikon mempunyai keupayaan untuk mengurangkan kesan getaran sehingga 86.67%. Kesimpulannya, getah silikon dipilih sebagai bahan terbaik untuk isolasi getaran dalam sistem termoakustik.

ACKNOWLEDGEMENT

First and foremost, I would like to express my deepest appreciation and gratitude to my supervisor, Ts. Dr. Asriana Binti Ibrahim from the Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka (UTeM), for her essential supervision, advice, the contribution of ideas, guidance, suggestions, and motivation towards the accomplishment of this project report.

I would also like to express my sincere acknowledgement to Dr. Fatimah Al-Zahrah Binti Mohd Sa'at for her motivation and encouragement on thermoacoustic systems. I would also acknowledge my friends, Ahmad Azimuddin and Mohd Firdaus, for providing their help, support, and motivation. This project would not have been completed without their assistance. Specific thanks to my parents, families, and friends, who have given me all the moral encouragement throughout the entire project up to this stage.

Special thanks to Fakulti Kejuruteraan Mekanikal, Universiti Teknikal Malaysia Melaka (UTeM), for the technical assistance provided in completing this project in time.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBEREVATIONS

LDV	-	Laser Doppler Vibrometer
IEPE	-	Integrated Electronic Piezoelectric
SREIs	-	Steel-Reinforced Elastomeric Isolators
FREIs	-	Fiber-Reinforced Elastomeric Isolators
NBR	-	Nitrile-Butadiene Rubber
ACN	-	Acrylonitrile
QZS	-	Quasi-Zero Stiffness
CFCs	-	Chlorofluorocarbons
PVC	-	Polyvinyl Chloride
DDS	-	Direct Digital Synthesis
DAQ	-	Data Acquisition
FFT	-	Fast Fourier Transform

LIST OF SYMBOLS

V	-	Volume
h	-	Height
R	-	Outer radius
r	-	Inner radius
m	-	Mass
ρ	-	Density
I	-	Area moment of inertia
k	-	Stiffness
E	-	Young’s Modulus
L	-	Length
W_n	-	Natural frequency
ζ	-	Damping ratio
c	-	Damping coefficient
T	-	Transmissibility
λ	-	Wavelength
f		Frequency
ε	-	Elongation at break
δ_k	-	Thermal penetration depth
δ_v	-	Viscous penetration depth

k	-	Thermal conductivity of gas
ρ	-	Density of gas
C_p	-	Specific heat at constant pressure
ω	-	Angular frequency of the sound wave

-

CHAPTER 1

INTRODUCTION

1.0 Background

Vibrations that happen inside a structure or system are still one of the significant problems that occur in the industrial sector. The types of vibration that happen in a system are consist of two types, namely torsional and linear vibrations (Adeoye, 2019). Torsional vibration is difficult to recognize as the vibrations cannot be felt. Vibrations that are caused by factors such as misalignment, imbalance, looseness, and wear in machine parts are categorized as linear vibrations, which can easily be felt, heard, and seen. Misalignment in the machine happens when the machine shaft, namely motor and pump, is not in a straight line due to shifting of components or improper reassembly after maintenance work. Imbalance in rotating machinery consists of three types, namely static unbalance, coupled unbalance, and dynamic unbalance. Generally, an imbalance is a heavy spot in rotating machinery, and it causes vibration as the unbalance weight rotates around the machine's axis, thus creating a centrifugal force.

The effect of vibration becomes greater as the machine speed increases. Vibrations are undesirable as they may affect the reliability and durability of machinery systems or structures. It also paves the way for other issues such as damage, abnormal machine stopping, or system failure. However, vibration is actually an indication of a problem that happens deep inside a structure. Therefore, the ability to detect vibration measurement is a crucial and vital countermeasure to prevent these problems from becoming severe.

Unused thermal energies such as exhaust heat from factories and solar light cannot be used due to the incognizance of the thermoacoustic system during the early years. A thermoacoustic system or thermoacoustic phenomenon is an event that enables the correlative energy conversion between heat and sound (Kurata, 2020 and Shiraki, 2019). The process that takes place in this system is that the unused thermal energy is being converted into sound energy. This means that electric power and cold energy can be extracted or utilized by reconversion (Kurata, 2020). For instance, the unused energy could be as a power source for an electric generator, cooling facility, or air conditioner. The information and understanding of this system can be utilized effectively as an environmental problem is getting uncontrollable these days. The configuration for a thermoacoustic system is consists of a vibration source, resonator tube, support, and a stack. Stack is the most important part of the thermoacoustic system as heat exchange, or temperature difference, is generated through the two (2) stacks. However, the study of heat is not included in this research.

A thermoacoustic system can enhance and employ those problems into another form of energy that will ease and benefits human life. Nevertheless, in a thermoacoustic system application, vibration may also occur due to many factors. This vibration may affect and leads to a decrease in the efficiency of the thermoacoustic system, increased unplanned downtime, consume excess power, and increase safety issues. As a means to reduce the vibration energy in a system, a vibration isolator and vibration damper could be added or applied to the system. A vibration isolator acts as a medium to reduce and control the unwanted vibration, while a vibration damper is used to absorb the vibration that emerges from a vibrating body. According to Adeoye (2019), the methods used to reduce the vibration are by applying elastomeric isolations and spring isolators.

1.1 Problem Statement

In the industrial sector nowadays, machinery is exposed to vibration. Vibrating machinery had become one of the major problems that would later lead to other problems such as it creates noise, cause safety problems, and leads degradation in plant working conditions. Thermoacoustic systems are also experiencing the same problems as other vibrating machinery. Vibration in a thermoacoustic system can cause higher power consumption. If vibration is continuously unchecked and not monitored, it could accelerate the rates of wear, damage the structure parts, and, even worse, system failure or breakdown. Development in vibration measurement is essential as the industry keeps growing with time. Hence, the vibration measurement device needs to be ultra-modern in order to keep abreast with the arising problem. The common device used for vibration analysis is the accelerometer. It is commonly used due to its high impedance and sensitivity. It also has a high-frequency response, and it uses a built-in signal conditioning circuit to measure capacitance. Upon detecting and measuring the vibration levels in a thermoacoustic system, a solution to reduce the vibration must be presented. Different types of vibration isolators are proposed to ensure that the system is functioning efficiently without any increasing vibration with time. To successfully implemented the solution suggested, a vibration measurement on a small-scale thermoacoustic test rig must be proposed.

1.2 Objective

1. To perform vibration measurements on a small-scale thermoacoustic test rig.
2. To shortlisted three (3) best isolators to reduce the vibrational effect of a small-scale thermoacoustic test rig.
3. To evaluate the selected isolators in vibrational reduction of a small-scale thermoacoustic test rig.

1.3 Scope of Project

1. The measurement of a vibrating surface is using an accelerometer.
2. Only the acceleration of vibration is measured by measuring the x and y displacement of a small-scale thermoacoustic test rig.

CHAPTER 2

LITERATURE REVIEW

2.0 Overview

The literature review of this project is carried out by researching the previous study related to vibration, including vibration measurement, vibration measurement equipment, thermoacoustic test rig, and vibration isolator. A review of the accelerometer, which is pertinent and relevant to the working principle of contact type for vibration measurement, is also provided.

2.1 Vibration

Vibration is a system's response to a dynamic disturbance. The back-and-forth movement or oscillations that happen inside a machine or system, such as drive motors, belts, shafts, powered devices, bearing, gears, and other elements or part in a machine, is the vibration in motorized machinery. As illustrated in Figure 2.1, vibration in a system can be categorized into two (2) types, namely the torsional and linear vibration (Adeoye, 2019). Torsional vibration is the angular vibration of an object, and usually, it is difficult to detect as it cannot be seen by naked eyes. These torsional vibrations are caused by the superposition of angular oscillations along with the entire structure of a propulsion shaft system, including the motor crankshaft, the propeller shaft, flexible coupling, engine, gearbox, and along the intermediate shaft (Litvinenko, 2019). As for the linear vibrations, they can easily be felt, heard, and seen. Looseness of parts in a machine, misalignment, imbalance, and wear are classified as linear vibration in machinery.

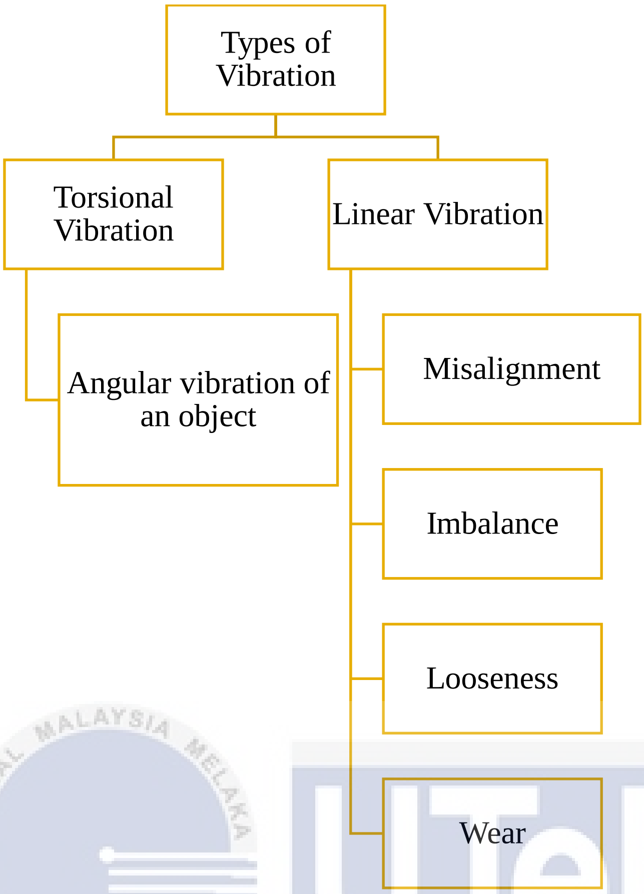

Figure 2.1 Types of Vibration

A vibration motion can also be in the form of oscillating, reciprocating, and periodic vibration. It can also be a harmonic or random vibration. Harmonic vibration arises due to the vibration's frequency and magnitude in a system are constant (Yu, 2018). In contrast, random vibration occurs when the vibration's frequency and magnitude vary with time. The effects of vibration may also vary, according to how long does the system has been exposed to vibration and whether proper maintenance has been done to the system or machine. Vibration may accelerate wear rates of machines or components, lead to degradation in plant working conditions, lead to quality and safety issues, unscheduled downtime, and repairing work (Shanbhag, 2021).

In some cases, vibration can damage components so severely, and this will lead to catastrophic failure of the machine or system. In consequence, proper machine monitoring and vibration measurement provide greater control over component's safety and availability. Vibration serves as an indicator of machine health, allows preventive maintenance at an early stage, reduces unscheduled downtime, and prevents machine failure.

2.2 Vibration Measurement

The vibration characteristics may be quantified in terms of displacement, velocity, and acceleration, and these three (3) characteristics depend on the amplitude and vibration frequency of a system. Displacement means the amplitude between the peaks of vibration. One of the applications of displacement sensor is it operates on the principle of Eddy current, and it is suitable to be used for vibration measurement in the frequency range of 1 to 1500 Hz and low amplitudes. The common vibration problem that uses this sensor is during the vibration measurement for sleeve bearing.

As for the acceleration sensor or the accelerometer, it utilizes the principle of piezoelectric, and it is categorized as the contact-type of vibration measurement. (Steiner, 2021). In vibration measurement, acceleration is measured in the unit of meter per second per second (m/s^2) or G, where 1 G is equal to the acceleration due to gravity Resulting from its constant signal over a wide range of frequency, this type of sensor is suitable for all types of vibration measurement. However, in some applications, there are a few limitations for the contact type, such as the mass of the accelerometer might affect the vibrating object.

The velocity of vibration is measured in peak units, meter per second (m/s). The three directions of vibration movement of the machine for every second are axial, vertical, and horizontal (Dionisio, 2021). As compared to accelerometers, velocity sensors have lower sensitivity for high-frequency vibrations. Velocity sensors can be used for low and medium frequency measurements that are useful to perform vibration measurement for machinery. The velocity signal of velocity sensors is generated by using an electromagnetic system.