A STUDY OF VIBRATION FOR THERMOACOUSTIC SYSTEM

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled "A Study of Vibration For 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 and father.

Thanks to the non-stop encouragement and guide given by my honourable supervisor, Ts. Dr. Asriana Binti Ibrahim, I am able to complete the task successfully.

ABSTRACT

Vibrations lead to fatigue failure or damage that is harmful to the supporting structures of the device. It also transferred to other parts of the system and affected the experimental result. The vibrations of the thermoacoustic could also affect the system during the testing activities. Higher vibrations will cause an increase in unwanted streaming flow in the thermoacoustic system. The vibration problem can be solved by choosing suitable methods and approaches. Therefore, this project was carried out to study the vibration for the thermoacoustic system in Turbo Machinery Laboratory, UTeM using comparison method on suitable isolator materials to reduce vibration transmissibility. This project begins by researching the idea of the thermoacoustic system and studying how vibrations can occur in the system and how the vibrational problem can be minimized. In theoretical calculation, the mathematical modeling of the vibrational system is developed to determine the natural frequency of the thermoacoustic test rig. Then, the initial vibration measurement of the thermoacoustic test rig was conducted to determine the actual natural frequency of the test rig. Measurement only focuses on the structure of the system. After that, the isolator materials will be short-listed to find the suitable elastomer. A comparison of the properties of isolator materials will be conducted to identify the best material and its effectiveness in reducing the vibration. Finally, the best isolator material will be proposed to minimize the vibration problem in this system. Silicone rubber was selected as an isolator material in this project.

ABSTRAK

Getaran menyebabkan kegagalan atau kerosakan yang membahayakan struktur penyokong peranti. Ia juga dipindahkan ke bahagian lain dari sistem dan akan mempengaruhi nilai data eksperimen. Hal yang sama berlaku untuk pelantar pengujian sistem termoakustik di mana semasa aktiviti eksperimen pelantar menghasilkan getaran yang lebih tinggi yang dapat menyebabkan peningkatan aliran yang tidak diingini dalam aliran termoakustik. Kaedah yang betul termasuk pendekatan yang berkesan diperlukan untuk mengurangkan masalah getaran kepada sistem. Oleh itu, projek ini dilaksanakan untuk mengkaji getaran sistem termoakustik di Makmal Mesin Turbo, UTeM menggunakan kaedah perbandingan pada bahan pengasingan yang sesuai untuk mengurangkan transmisi getaran. Projek ini dimulakan dengan meneliti idea sistem termoakustik dan mengkaji bagaimana getaran boleh berlaku dalam sistem dan bagaimana masalah getaran dapat diminimumkan. Dalam pengiraan teori, sistem pemodelan getaran dilaksanakan untuk menentukan frekuensi semula jadi pelantar ujian termoakustik. Kemudian, pengukuran getaran pelantar ujian termoakustik dilakukan untuk menentukan frekuensi semula jadi pelantar ujian. Pengukuran hanya tertumpu pada struktur untuk sistem. Selepas itu,bahan pengasingan terbaik akan dicadangkan untuk mengurangkan getaran. Perbandingan sifat bahan pengasing dilakukan untuk mengenal pasti bahan terbaik dan keberkesanannya dalam meminimumkan getaran. Getah silikon dipilih sebagai bahan pengasing dalam projek ini.

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LIST OF ABBEREVATIONS

MSD	Mass-Spring-Damper
MDOF	Multi Degree of Freedom
SDOF	Single Degree of Freedom
DAQ	Data Acquisition
ADC	Analog to Digital Converter
PVC	Polyvinyl Chloride

LIST OF SYMBOLS

m	=	Mass
k	=	Spring stiffness
c	=	Damping coefficient
t	=	Time
ω_n	=	Angular natural frequency
π	=	Radian
f_n	=	Frequency
x	=	Displacement
$\ddot{x}$	=	Second derivatives of x
W	=	Weight
g	=	Gravity
ρ	=	Density
V	=	Volume
ℓ	=	Length
w	=	Width
h	=	Height
E	=	Young's Modulus
A	=	Area of cross section
I	=	Area moment of inertia
L	=	Original length
F_e	=	Excitation force
F_t	=	Force transmitted
T_f	=	Transmissibility
ζ	=	Damping ratio

CHAPTER 1

INTRODUCTION

1.1 Background

Vibrations lead to fatigue failure or damage that is harmful to the supporting structures of the device. It also transferred to other parts of the system and affecting to result of the experiment when the system is running. Meanwhile, the worse vibration causes a great deal of force and, therefore, a great deal of stress (Ahirroa et. al, 2018). This is supported by (Bao et. al, 2018) state that when the compressor vibrates too large, it will cause significant stress and strain of connection pipes and may cause the pipes to break. When this situation arises, resonance may occur if the system's natural frequencies are close to the source frequency of excitation. According to (Jin et. al, 2019) the vibration of the machine not only affects the efficiency and effect of the operation but also decreases the service life of the machine. In many cases, vibration problems also can happen because of the working process of the system and the unbalanced force of moving components in the system. The same applies to the thermoacoustic system test rig, where during the experimental activities, the rig produces higher vibration that could lead to an increase in unwanted streaming in the thermoacoustic flow environment. Therefore, suitable methods and approaches must be chosen wisely to minimize vibration problems for the system.

Grommet’s system was used to minimize the vibration, and results show that the natural frequencies moved far away from the excitation frequencies (Wu et. al, 2016). In the meantime, the structure of the system is of significant importance to the vibration problem. Using a robust and accurate design of support, proper mounting is needed to reduce vibration (Ahirroa et. al, 2018). The statement is also supported by (Jin et. al, 2019), where a double-layer vibration isolation system is used to reduce the vibration of an agricultural machinery engine. However, poor or no isolation from the vibration source to the attachment structure also causes a vibration problem in the thermoacoustic system. At this time, vibration energy can easily be passed to the other parts of the system.

1.2 Problem Statement

The thermoacoustic test rig is located in the Faculty of Mechanical Engineering Laboratory, as shown in Figure 1.1. Students use the rig to analyse fluid flow characteristics when the source of energy from sound is transformed to heat energy. In the current situation, the rig produces high vibration when the system is running for experimental experiments. This vibration may be caused by an internal system (change of sound to heat) and may be driven by an external system (machine structure).

Figure 1.1: Thermoacoustic test rig at Turbo Machinery Laboratory, UTeM (Saat et. al, 2019).

1.3 Objective

The objectives of this project are as follows:

1. To determine the natural frequency of the thermoacoustic test rig using the theoretical calculation.
2. Propose the material for the isolator to reduce vibration of the thermoacoustic test rig.
3. To evaluate the proposed isolator material.

1.4 Scope of Project

The scopes of the project are:

1. The only results of vibration measurement are present in this report. The frequency, amplitude (displacement, velocity, and acceleration), and transmissibility graph are obtained from a set of measures and Microsoft Excel Add-In (ME boost).
2. Only focus on the structure of the thermoacoustic test rig for the vibration problem.

CHAPTER 2

LITERATURE REVIEW

2.1 Thermoacoustic System

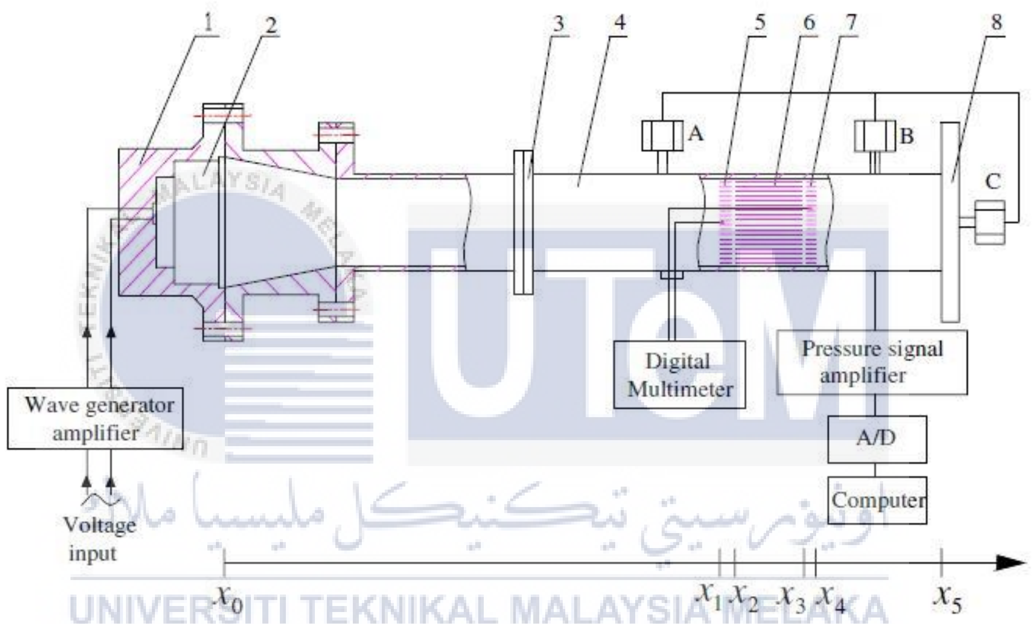
Power consumption is increasing day by day with the growth of technology. Refrigerators, televisions, smartphones, and even a monitoring system are examples of products demanding power from energy sources. But the effect on the ecosystem where there is a shortage of natural resources and environmental pollution. Therefore, sustainability and green technologies are essential and do not affect the environment. The thermoacoustic phenomenon converts heat energy and sound energy (Kitadani et. al, 2010). According to (Eisinger et. al, 2009; Eisinger et. al, 2008), states that systems with hot and cold gas-filled mixed enclosures can be subject to prominent thermoacoustic oscillations.

Thermoacoustic is a principle of science that can be used to produce a generator/electric power or a cooler/heater if specific conditions are met (Saat et. al, 2019). Through this approach, the waste heat and noise generated by the plant can be transformed into a new energy source. Indirectly, environmental impacts, especially noise pollution, can be minimized. Thermoacoustic systems require the transfer of heat and acoustic power into one another. The lack of moving parts, higher efficiency, low cost, usability of noble gases, and the likelihood of using low potential energy sources such as waste heat are the main merits of the thermoacoustic system (Kalra et. al, 2015). However, several factors influence the performance and the efficiency of the system itself, such as vibration problems.

To investigate the efficiency of the thermoacoustic system, experimental testing on the rig structure needs to be done. The thermoacoustic device consists of an acoustic conductor, such as a loudspeaker connected to a tube and filled with inert gases, which act as working fluids (Johari et. al, 2018). The acoustic to the thermal transfer of energy relies heavily on the oscillatory flow characteristics of fluid dynamics within the system. Therefore, experimental investigations, an experimental rig, can generate the proper oscillatory flow of thermoacoustic.

2.2 Thermoacoustic Test Rig

Thermoacoustic devices are not complexly designed but reliably, using the interconnection between heat and acoustics for power generation. For example, a thermoacoustic refrigerator comprises an acoustic source (loudspeaker), a resonator, a stack and two heat exchangers between its two ends, shown in Figure 2.1 (Tu et. al, 2005). Therefore, the most crucial component of any thermoacoustic device is a stack, which significantly enhances the performance of thermoacoustic devices.



1. Acoustic source cavity; 2. Electrodynamic loudspeaker; 3. Flange; 4. Resonator; 5. Cold heat exchanger; 6. Thermoacoustic stack; 7. Hot heat exchanger; 8. Rigid acoustic termination

Figure 2.1: The schematic diagram of test rig (Tu et. al, 2005).

The wave generator amplifier connected to the loudspeaker was used to launch sound waves, while the amplifier power was used to adjust the operating frequencies. This statement is also supported by (Putra et. al, 2013), where the amplifier was connected to the driver (loudspeaker) in a thermoacoustic refrigerator test rig to gain an understanding of its thermal efficiency and cooling rate shown in Figure 2.2. It was found that loudspeakers as low-cost linear alternators for thermoacoustic applications to convert acoustic power to electricity. According to (Vesely et. al, 2014) states that acoustic energy produces by a loudspeaker used to pump heat from a cold to a hot heat exchanger, shown in Figure 2.3. The wave is transmitted to the resonator by the acoustic driver (loudspeaker) with the desired frequency and power of the generator and the amplifier (Alamir, 2019). Figure 2.4 shows another schematic diagram of a standing wave thermoacoustic refrigerator, and Figure 2.5 shows the Schematic illustration of the tested thermoacoustic generator.

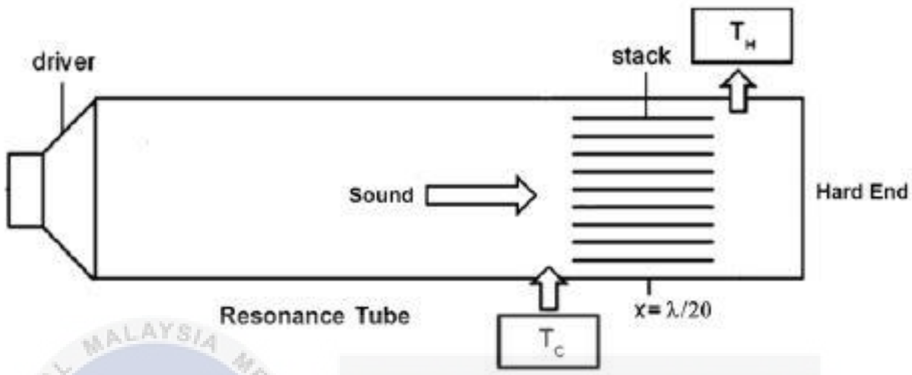


Figure 2.2: The schematic diagram of a thermoacoustic device (Putra et. al, 2013).

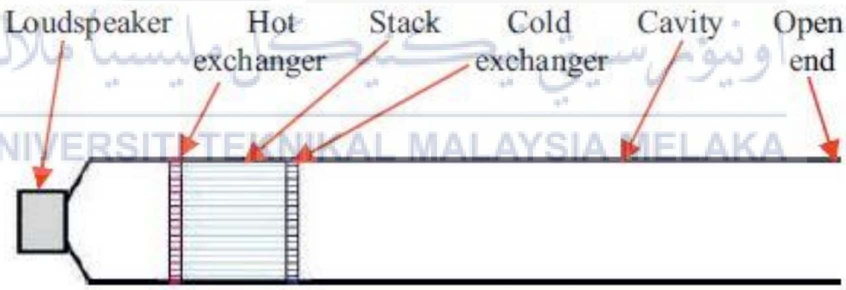


Figure 2.3: The schematic of a thermoacoustic heat pump (Vesely et. al, 2014).