STUDY ON INHOMOGENEOUS MICRO-PERFORATED PANEL SOUND ABSORBER WITH CROSS PERFORATION ARRANGEMENT

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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 “Study On Inhomogeneous Micro-Perforated Panel Sound Absorber With Cross Perforation Arrangement ” 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 (Plant Maintenance).

Signature :. .....

Name of Supervisor: .....

Date : .....

DEDICATION

To my beloved mother and father

ABSTRACT

Effect of inhomogeneous perforation for Micro Perforated Panel (MPP) has been discussed in the literatures but not for the MPP cross perforation arrangement. This project studies the effect of the cross-perforation arrangement to the sound absorption performance. The simulation was first conducted to simulate the performance of the MPP followed by the experimental validation. The experimental method was used to valid the simulation result. The project can be analysed by studying three main parameters effecting the sound absorption coefficient which are perforation ratio, hole diameter and cavity depth. The research found that the decreasing in hole diameter reduced the absorption bandwidth. Decreasing the perforation ratio shift the peak of absorption to lower frequency. Then, increasing the cavity depth increases sound absorption coefficient at low frequency. The simulation result of inhomogeneous MPP separation perforation has two peak frequencies because of each hole diameter reacts at own cavity depth, but for the experiment have only one peak frequency because the cross-sectional perforation reacts randomly on two cavity depths.

ABSTRAK

Kesan perforasi tidak homogen untuk Panel Perforasi Mikro (MPP) telah dibincangkan dalam literatur tetapi tidak untuk susunan perforasi silang MPP. Projek ini mengkaji pengaruh susunan perforasi silang terhadap prestasi penyerapan bunyi. Simulasi pertama kali dilakukan untuk mensimulasikan prestasi MPP diikuti dengan pengesahan eksperimen. Kaedah eksperimen digunakan untuk mengesahkan hasil simulasi. Projek ini dapat dianalisis dengan mengkaji tiga parameter utama yang mempengaruhi pekali penyerapan suara iaitu nisbah perforasi, diameter lubang dan kedalaman rongga. Penyelidikan mendapati bahawa penurunan diameter lubang mengurangkan lebar jalur penyerapan. Menurunkan nisbah perforasi mengalihkan puncak penyerapan ke frekuensi yang lebih rendah. Kemudian, meningkatkan kedalaman rongga meningkatkan pekali penyerapan bunyi pada frekuensi rendah. Hasil simulasi perforasi pemisahan MPP yang tidak homogen mempunyai dua frekuensi puncak kerana setiap diameter lubang bertindak balas pada kedalaman rongga sendiri, tetapi untuk eksperimen hanya mempunyai satu frekuensi puncak kerana perforasi keratan rentas bertindak balas secara rawak pada dua kedalaman rongga.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBEREVATIONS

MPP	Micro Perforated Panel
SAC	Sound Absorption Coefficient

LIST OF SYMBOLS

c	=	speed of sound wave
ρ	=	density of air
η	=	viscousity of air
P	=	perforation ratio
t	=	thickness of plate
d	=	diameter of hole
α	=	sound absorption coefficient
ω	=	angular frequency
z	=	impedance
D	=	cavity of depth
An	=	Area of all hole diameter
As/2	=	Area of half sample plate

CHAPTER 1

INTRODUCTION

1.1 Background

The growth of industries has contributed to an increase in sound pollution to the environment. People are exposed to noise in high external and internal environments every day. Externally, noise is generated from the engine of a car or train, and internally, noise is generated by echoes of sound such as speakers. In this case, noise sound can contribute to human health problem such as stress, blood pressure rises and hearing damage if not control.

Sound is a form of energy which travels as a wave and the variety of sound exist due to different feature of a wave. The law of energy states that energy cannot be created or destroyed, but it can be transformed from one form to another. The same is true for sound cases. Acoustic energy is not destroyed but can be converted into harmless forms. That function is referred to the sound-absorbing materials. (Everest et al,2009).

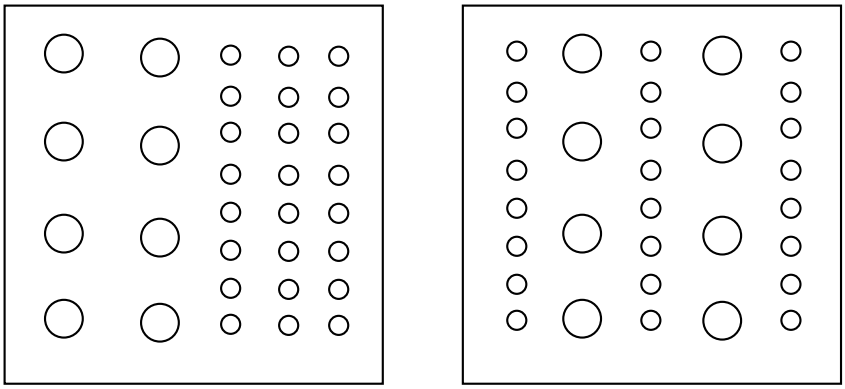
Sound absorbing materials can generally be classified as one of these types. It is a porous absorber, a panel absorber, and a volume or resonant absorber. Porous absorbers are the most effective absorbers at higher frequencies, while panel and volume absorbers are the most effective absorbers at lower frequencies. All these types of absorbers work the same. Sound is the vibration energy of air particles, and absorption can be used to eliminate vibration energy in the form of heat energy. Therefore, the acoustic energy is reduced. Little heat generation due to sound absorption. (Everest et al,2009).

Sound absorption is process of sound waves absorbed to eliminate echoes and reverberation from the sound source. In case of reverberation, an equation to calculate the reverberation had been published in 1900 or known as Sabine's reverberation equation. When Sabine came up with this equation while experimenting on his behalf, two instructors were adding or removing uniform seats, so they could explain the role of absorption in the reverberation chamber. He pointed out that the reverberation time depends on the number of rooms and their absorption. The greater the absorption, the shorter the reverberation time produced. Similarly, the larger the volume of the room, the longer the reverberation. This is because sound rarely enters the absorption chamber. (Everest et al,2009).

Perforated Panel widely used as sound absorption in the building, room or hall. Micro Perforated Panel (MPP) is reduce in size of perforated panel. It is simple panels with a few holes on the panel. The holes created on the panel consist with 2 size of diameter for the inhomogeneous and only one-hole size diameter for the homogeneous. Carbajo et al.2019 said in their journal that Maa recommends a flat MPP acoustic transfer impedance equation with circular perforations distributed periodically over the surface. Furthermore, if the perforation rate P is decreased or the diameter of the micro perforations is decreased, d affects the sound absorption coefficient increases.

1.2 Problem Statement

Effect of inhomogeneous perforation for MPP has been discussed in the literatures but not for the MPP cross sectional arrangement. In this case, this project will study the effect of the cross-sectional arrangement due to the sound absorption performance. The simulation will be first conducted to simulate the performance of the MPP followed by the experimental validation.



(a) (b)

Figure 1. 1 MPP with (a) Inhomogeneous series perforation and (b) Inhomogeneous cross perforation

1.3 Objective

The objectives of this project are as follows:

1. To study the sound absorption performance of MPP with inhomogeneous cross perforation with various parameters.
2. To perform experiment of sound absorption coefficient in impedance tube.

1.4 Scope of Project

The scopes of this project are as follows:

1. The mathematical modelling of sound absorption of MPP is performed using MATLAB software.
2. Simulation is only for normal incidence of sound.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In order to give well understanding and good review about this project research, this chapter will discuss about information that related. This chapter includes the study on the single layer MPP, effects of hole diameter, effect of perforation ratio, effect of cavity depth, effect of plate thickness and sound absorption for inhomogeneous MPP absorber. The result from the finding research of this parameter also will showed and briefly discussed in this chapter.

Basically, study on cross sectional arrangement is the extend study of the inhomogeneous perforation. The parameters used in the inhomogeneous perforation research also will use in this study to observe the behaviour when use the cross-sectional arrangement. Hence, the finding of this study also will compare to the finding from the inhomogeneous perforation.

2.2 Single Layer MPP

2.2.1 Characteristic

A single layer MPP is a thin plate consist with micro hole diameter tabulated on the surface plate as shown in Figure 2.1, which is one of the examples MPP sample. It is widely use in the world as a sound absorption because the characteristic of the MPP which are easy to maintain and withstand high temperatures suitable for outdoor application. As compared to others material such as conventional porous materials like foams and fibres

are difficult to maintain and cannot be used in environments with a temperature gradient. (Laly et al, 2018).

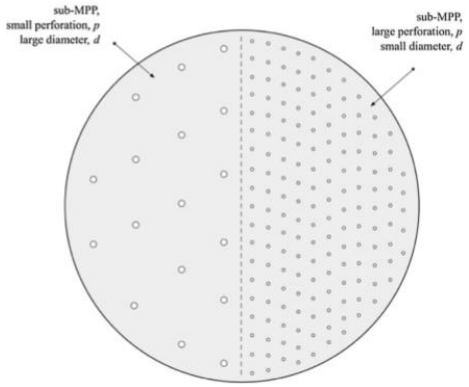


Figure 2. 1 Illustration of features of the inhomogeneous MPP sample (Mosa et al, 2019)

The surface of the plate does not affect the absorption curve as long as the effect of excessive perforation is taken into account. Means that, the distribution of the perforation over surface can be created. Because of that, MPP used as decorative object that can be matches with the colour and design of a room. The MPP can also be used in high-pressure situations such as wind tunnels, aircraft turbines or silencers.

For engineering problems represented by parametric models, sensitivity analysis can determine the effect of each model's input parameters on the desired output. Sensitivity analysis was performed on a single layer MPP absorber using a non-linear impedance model to emphasize the effect of input parameters on normal surface impedance and sound absorption coefficient. (Laly et al,2019)

2.2.2 Governing Equation

Suppose a sound wave is incident on the flat MPP absorber while neglect the effect of vibration to the panel since the panel backed with rigid wall. Its acoustic impedance can be determined using Maa's formula:

$$z_{MPP} = z_{resistance} + z_{reactance} = \mathrm{r} + \mathrm{j}\omega\mathrm{m} \quad (2.1)$$

Where acoustic impedance is consisting of resistive part and reactance part.

$$r = \frac{32\eta t}{\rho c d^2 P}\left(\sqrt{1 + \frac{x^2}{32} + \frac{xd\sqrt{2}}{8t}}\right) \quad (2.2)$$

$$m = \frac{t}{Pc}\left(1 + \left(9 + \frac{x^2}{2}\right)^{-\frac{-1}{2}} + \frac{0.85d}{t}\right) \quad (2.3)$$

$$x = \frac{d}{2}\sqrt{\frac{\omega\rho}{\eta}} \quad (2.4)$$

where the terms r and m are the normalized specific acoustic resistance and the normalized specific acoustic reactance, respectively, t is the panel thickness, ρ is the density of air, ω is the angular frequency, c is the speed of sound wave, P is the perforation ratio, d is the diameter of the holes and η is the viscosity of air.

The MPP is usually located in front of a rigid wall with an air cavity depth D to maximise the sound absorption mechanism. The impedance of the air cavity is

$$z_D = -jcot\left(\frac{\omega D}{c}\right) \quad (2.5)$$

For inhomogeneous MPP absorber system, the total acoustic impedances is expressed as

$$z_{tot} = r + j\omega m + z_D \quad (2.6)$$

The total sound absorption coefficient is given by

$$\alpha = \frac{4Re\{z_{tot}\}}{[1+Re\{z_{tot}\}]^2+[Imag\{z_{tot}\}]^2} \quad (2.7)$$

2.3 Parameters Study

2.3.1 Effects of Hole Diameter

Basically, MPP absorber build in a few types of hole such as circular, tringle, square and slits. All these types will produce various effect to the sound absorption coefficient. Fabrication of MPP with non-circular or irregular cross section is processed by laser or drill machines. (Ning et al, 2016). The present of perforated panels with slit results in poorer acoustic performance than perforated panels with round holes. This is because more air is released behind the slit plate than the circular holes. Therefore, choosing a perforated panel with slit over a perforated panel with circular holes may be economically advantageous, but from an acoustic performance perspective, it is adequate.

Typically, the MPP absorption coefficient of the triangle cross section is higher than the cross-section of the slot and the square when the perforation circumference is the same, while being almost identical to the perforation with the same cross-section as shown at Figure 2.2.

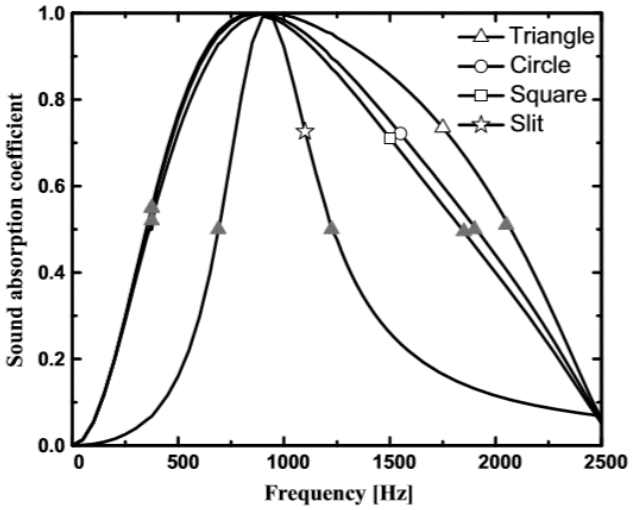


Figure 2. 2 Sound absorption coefficients of MPP absorbers with different cross-sectional shape (Ning et al, 2016)