Faculty of Mechanical Engineering

A STUDY OF SOUND ABSORPTION PERFORMANCE OF MICRO-PERFORATED PANEL ABSORBERS WITH IRREGULAR HOLES DISTRIBUTION

Esraa Amer Jameel

Master of Science in Mechanical Engineering

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ESRAA AMER JAMEEL

A thesis submitted
in fulfilment of the requirements for the degree of Master of Science
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DECLARATION

I declare that this thesis entitled " A Study of Sound Absorption Performance of Micro-Perforated Panel Absorbers with Irregular Holes Distribution" is the result of my research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

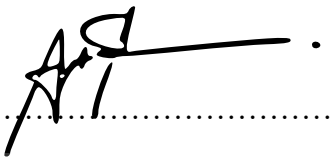
Signature : .....

Name : Esraa Amer Jameel

Date : 08/15/2022

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature : 

Supervisor Name : Associate Professor Dr. Azma Putra

Date : 18 August 2022

DEDICATION

It is dedicated to Allah S.W.T. Almighty and Rasul-Allah S.A.W. Thanks also to all people who stand with me.

To my father, who not forget me

For his prayers and care for me

To my mother

A strong and gentle soul who taught me to trust in Allah, believes in hard work and so taught me that much could be done with less

To my brother and sisters

To my husband who helps me and support me in all aspects of my live

To my children,

The reason for what I have become today

Thanks for your great support and continuous care

ABSTRACT

The demand for comfort environment in terms of the noise level is important in buildings such as classrooms, health care facilities, and auditoriums. Mineral and synthetic porous absorbing materials are commonly used for this purpose. The micro-perforated panel absorber (MPP) is increasingly popular as one of the sound absorbing systems with high acoustical performance and more environmentally friendly to the traditional porous materials. However, the only drawback for the MPP is its narrow band of absorption frequency. This study presents the effect of holes distribution over the MPP surface on sound absorption performance for a single layer MPP model and to improve the absorption frequency bandwidth especially to the lower frequency range. The simulation employed the finite element method (FEM) using COMSOL Multiphysics by considering the visco-thermal effects to calculate acoustic impedance and absorption coefficient. For both homogeneous and inhomogeneous perforation are considered in the analysis. The results demonstrate that by spreading out the holes around the edge of the MPP, the absorption coefficient can be seen to shift to the lower frequency. All results have also been shown to have good agreement with the experiment

KAJIAN PRESTASI PENYERAPAN BUNYI PANEL BERTEBUK MIKRO DENGAN TABURAN LUBANG TIDAK TERATUR

ABSTRAK

Persekitaran yang selesa menjadi keperluan penting bagi sesebuah bangunan seperti bilik darjah, kemudahan kesihatan dan auditorium. Kebiasaannya, bahan mineral dan bahan sintetik yang menyerap dan berliang digunakan untuk tujuan ini. Panel penyerap bertebuk-mikro (MPP) kini semakin popular sebagai salah satu sistem penyerapan bunyi yang mempunyai prestasi akustik yang tinggi dan lebih mesra alam berbanding dengan bahan berliang tradisional. Walau bagaimanapun, satu-satunya kelemahan bagi MPP adalah frekuensi penyerapan jalur sempit. Kajian ini menunjukkan kesan taburan tebukan pada permukaan panel terhadap prestasi penyerapan untuk model MPP lapisan tunggal dan untuk meningkatkan frekuensi penyerapan jalur lebar terutamanya kepada julat frekuensi rendah. Simulasi dengan menggunakan COMSOL Multiphysics melalui kaedah unsur terhingga (FEM) mempertimbangkan kesan visco-termal untuk mengira impedans akustik dan pekali penyerapan. Kedua-dua tebukan homogen dan tidak homogen diambil kira dalam analisis. Hasil menunjukkan bahawa dengan menyebarkan lubang pada pinggir panel (MPP), pekali penyerapan dilihat menganjak ke frekuensi yang lebih rendah. Semua hasil juga telah menunjukkan persetujuan yang baik dengan hasil eksperimen.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Alpha	-	Sound Absorption Coefficient
ECM	-	Electrical Circuit Method
FEM	-	Finite Element Method
iMPP	-	Inhomogeneous Micro-Perforated Panel
MPP	-	Micro-Perforated Panel
MPPs	-	Micro-Perforated Panel of Surface
PP	-	Perforated Panel
SL	-	Single Layer
SL-iMPP	-	Single Layer Inhomogeneous Micro-Perforated Panel
SL-MPP	-	Single Layer Micro-Perforated Panel

LIST OF NOMENCLATURES

Ah	-	The total hole area
As	-	The entire surface area of the panel before holes
b	-	The distance between hole centers, (mm)
c	-	Speed of sound in air (m/s)
c_p	-	The specific heat at constant pressure
D	-	Depth of the air cavity, (mm)
d	-	Hole diameter, (mm)
di	-	The tube inner diameter of
do	-	The tube outer diameter
f	-	Frequency, (Hz)
f_{max}	-	The highest computed frequency
I	-	Unit matrix.
Imag(Z)	-	The imaginary part of the specific acoustic impedances of the MPP
j	-	Imaginary unit
k	-	Wave number = ω/ c [m^{-1}]
L	-	Length of impedance tube
m	-	The normalised specific acoustic reactance
N1	-	Number of holes in left hand sub-MPP
N2	-	Number of holes in right hand sub-MPP
p	-	Hole Perforation ratio, (%)

PML	-	Perfectly-Matched-Layer
P_i	-	The total incident sound pressure at the front surface of the MPP (front tube side)
P_{out}	-	The total transmitted sound pressure at the back surface of the MPP (back cavity side)
P_{trans}	-	The total transmitted sound pressure at the back surface of the MPP (back cavity side v the bulk particle velocity of the fluid component in wave direction.
Q	-	Heat source
r	-	Hole radius, (mm)
r	-	The normalised specific acoustic resistance
R	-	The pressure reflection coefficient
Real(Z)	-	The real part of the specific acoustic impedances of the MPP
t	-	Panel thickness, (mm)
T	-	Air temperature
T_o	-	Absolute temperature zero, T_o=293.15 K
u	-	Wave velocity
v	-	The particle velocity of the fluid
Z_D	-	The specific acoustic impedance of the air cavity
Z_{MPP}	-	Acoustic impedance of panel
$\mathrm{Z_{total}}$	-	The total specific acoustic impedance of the homogeneous and inhomogeneous MPP absorber system
α	-	The sound absorption coefficient of the MPP
α_p	-	The specific heat at constant pressure

ω	-	The angular frequency = 2 πf [rad/s]
μ_B	-	The bulk viscosity describes losses due to compressibility
λ	-	The wavelength
ρ	-	Air density (kg/m^3)