Faculty of Mechanical Engineering

MODELLING THE ACOUSTIC PERFORMANCE OF INHOMOGENEOUS MICRO-PERFORATED PANEL ABSORBER

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Doctor of Philosophy

2021

MODELLING THE ACOUSTIC PERFORMANCE OF INHOMOGENEOUS MICRO-PERFORATED PANEL ABSORBER

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A thesis submitted
in fulfilment of the requirements for the degree of Doctor of Philosophy

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this thesis entitled "Modelling the Acoustic Performance of Inhomogeneous Micro-Perforated Panel Absorber" 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.

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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 Doctor of Philosophy.

Signature	:	……………………………………….
Supervisor Name	:	Associate Professor Dr. Azma Putra
Date	:	……………………………………….

DEDICATION

Dedicated to Allah S.W.T. Almighty and Rasul-Allah S.A.W. Thanks also

To the Father in My Heart,

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 thought so much could be done with less

To my brother and sister

To my Wife who stands with me and supports me in all aspects of my life

To my Children

The reason of what I have become today

Thanks for your wholehearted support and continuous care

ABSTRACT

Micro-perforated panel (MPP) absorber is increasingly gaining more popularity in noise control as a sound absorber given its facile installation, long durability, environmental friendliness and attractive appearance and as an alternative to the classical porous acoustics materials. A single MPP absorber typically features a Helmholtz resonator with a high absorption amplitude, but narrow absorption bandwidth. The main objective of this study is to obtain a wider sound absorption bandwidth by proposing an inhomogeneous perforation technique. The first step is to study the acoustic performance of a single layer MPP containing holes of two different sizes and ratios and with multiple cavity depths. Thereafter, for more improvement of the absorption bandwidth, this single MPP is cascaded with another single MPP to form a double-layer MPP model of inhomogeneous perforation. Mathematical models based on the equivalent electrical circuit method are proposed, and the absorption coefficient is calculated under a normal incidence of sound. The results show that the introduction of inhomogeneous perforation technique improves the absorption performance of the single layer MPP absorber compared to the homogenous one, especially with multi-cavity depths. The MPP layer should consist of two sets of perforation parameters set in an equal arrangement in two sub MPP areas; one of smaller perforation ratio with large hole diameter and the other of larger perforation ratio with smaller hole diameter. The proposed double layer inhomogeneous MPP model exhibits significantly wider sound absorption bandwidth and higher sound absorption amplitude than that of the conventional double-layer and even triple-layer homogeneous MPPs. The results demonstrate that the absorption bandwidth can be effectively controlled to higher frequencies region by reducing the air cavity between the two inhomogeneous MPP layers, and by decreasing the cavity depth behind the sub-MPP with small hole diameter and high perforation ratio. For the low frequency improvement, this can be achieved by increasing the cavity depth behind the sub-MPP with large hole diameter-small perforation ratio. The theoretical results were validated with the experiments by using the impedance tube method with a good agreement. This study also presents an empirical mathematical model for the single layer, multi cavity inhomogeneous MPP to conveniently obtain the required MPP parameters to have the half-absorption bandwidth of absorption coefficient.

PEMODELAN PRESTASI AKUSTIK DARI PANEL PENYERAP BERTEBUK-MIKRO TIDAK SERAGAM

ABSTRAK

Penyerap panel bertebuk-mikro (MPP) menjadi semakin popular dalam kawalan bunyi disebabkan pemasangannya yang mudah, tahan lama, mesra alam dan mempunyai rupa yang menarik serta sebagai alternatif kepada bahan penyerap akustik berliang klasik. Penyerap MPP tunggal biasanya mempunyai ciri-ciri tipikal seperti penyalun Helmholtz dengan amplitud penyerapan tinggi, tetapi dengan lebar jalur penyerapan yang sempit. Objektif utama kajian ini adalah bagi mendapatkan lebar jalur penyerapan bunyi lebih besar dengan mencadangkan teknik tebukan tak homogen. Langkah pertama adalah untuk mengkaji prestasi panel bertebuk-mikro tunggal yang mempunyai dua saiz dan nisbah lubang yang berlainan dan pelbagai kedalaman rongga. Selepas itu, untuk meningkatkan jalur penyerapan, MPP tunggal ini disusun dengan satu lagi MPP tunggal untuk membentuk model dua lapisan MPP bertebuk tak homogen. Model matematik yang dicadangkan adalah berdasarkan model litar elektrik setara dan pekali penyerapan dikira pada bunyi tuju normal. Hasil kajian menunjukkan pengenalan teknik tebukan tak homogen meningkatkan prestasi penyerapan lapisan MPP tunggal berbanding dengan teknik homogen, terutamanya dengan pelbagai kedalaman rongga. Lapisan MPP hendaklah terdiri daripada dua set parameter tebukan yang ditetapkan pada susunan sama dalam dua kawasan sub MPP, satu nisbah tebukan sedikit dengan diameter lubang besar dan satu lagi bernisbah tebukan lebih banyak dengan diameter lubang kecil. Model dua lapisan MPP tak homogen yang dicadangkan mempamerkan kelebaran jalur penyerapan yang lebih ketara dan amplitud penyerapan tinggi berbanding dengan dua-lapisan dan tiga-lapisan MPP homogen konvensional. Hasil kajian menunjukkan bahawa jalur penyerapan dikawal secara efektif ke frekuensi tinggi dengan mengurangkan rongga udara di antara dua lapisan MPP tak homogen, dan dengan mengurangkan kedalaman rongga di bahagian belakang sub-MPP berdiameter kecil dan tebukan bernisbah tinggi. Bagi menambah baik frekuensi rendah, kedalaman rongga di belakang sub-MPP dengan diameter lubang besar-bernisbah tebukan sedikit ditingkatkan. Hasil teori disahkan dengan eksperimen menggunakan kaedah tiub impedans menunjukkan hasil yang baik. Kajian ini juga menunjukkan model matematik empirik bagi MPP tunggal, pelbagai kedalaman rongga MPP tak homogen digunapakai untuk mendapatkan parameter MPP yang diperlukan bagi mencapai separuh-jalur penyerapan daripada pekali penyerapan.

ACKNOWLEDGEMENTS

Alhamdulillah, first and foremost, I would like to praise to Allah S.W.T, the Almighty for giving me a little strength and granting me the capability to do my thesis. Heartiest gratitude to my supervisors: Associate Professor Dr. Azma Putra and Associate Professor Dr. Roszaidi bin Ramlan for their kind advice, guidance, encouragements, and supports during my doctoral research and study. The achievements and completion of the thesis will be very hard to be possible without their valuable, sincere and relentless supervision. I would like to thank my family, especially to my wife, and my children for their great support and encourage. Throughout my doctoral research, there have been supporting and assistance of several people who helped me to finish this research. Therefore, it is an opportunity to thank and appreciate these people's great efforts. I want to express my thanks to Mr. Johardi, from the laboratory vibro-acoustic in Faculty of Mechanical Engineering (FKM), for his assistance, time and efforts during the measurement and fabrication. To all my colleagues and fellow friends, especially Dr. Osam H. Attia from the University of Baghdad, I would like to express my thanks for their support. Last, thank you to everyone who supported me directly or indirectly and always remember me and praying for my success. Thank you very much.

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