



Faculty of Mechanical Engineering

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



Esraa Amer Jameel

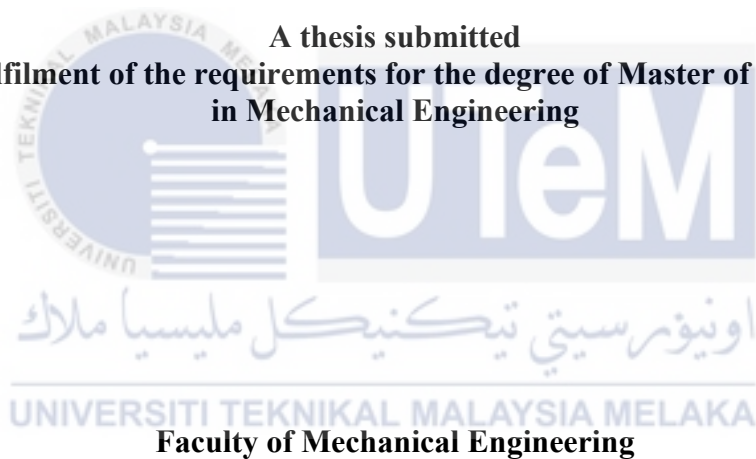
Master of Science in Mechanical Engineering

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**A STUDY OF SOUND ABSORPTION PERFORMANCE OF MICRO-
PERFORATED PANEL ABSORBERS WITH IRREGULAR HOLES
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ESRAA AMER JAMEEL

**A thesis submitted
in fulfilment of the requirements for the degree of Master of Science
in Mechanical Engineering**





UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

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.



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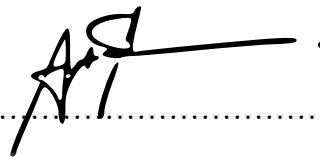
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APPROVAL

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 Master of Science in Mechanical Engineering.

Signature

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Supervisor Name

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Date

: 18 August 2022



اونيورسيتي تيكنيكل مليسيا ملاك
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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 tebukn 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

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF ABBREVIATIONS	xvi
LIST OF NOMENCLATURE	xvii
LIST OF CONSTANTS	xx
LIST OF PUBLICATIONS	xxi
 CHAPTER	
1. INTRODUCTION	1
1.1 Background	1
1.2 Problem statement	5
1.2.1 General Problem	5
1.2.2 Research issues	5
1.2.3 Research gap	6
1.3 Objective	7
1.4 Scope of study	7
1.5 General methodology	8
1.6 Thesis outline	9
 2. LITERATURE REVIEW	10
2.1 Introduction	10
2.2 Acoustical parameters	11
2.2.1 The panel thickness	12
2.2.2 The diameter of panel hole	12
2.2.3 The space between the panel holes	12
2.2.4 The panel perforation ratio	12
2.2.5 The air cavity depth	13
2.3 Recent studies on MPP technique	13
2.4 Finite-element-method (FEM)	20
2.5 Past studies on MPP with Finite element method	22
2.5.1 FEM models with considering thermal effects	27
2.6 Computer simulation based on FEM	32
2.6.1 COMSOL	32
2.7 Impedance tube method	33
2.8 Critical discussions	34

3. RESEARCH METHODOLOGY	36
3.1 Introduction	36
3.2 Microperforated panel absorber (MPP)	38
3.3 Acoustic impedance of the MPP using equivalent circuit method (ECM)	38
3.3.1 Basic MPP	38
3.3.2 Inhomogeneous MPP	41
3.4 Acoustic impedance MPP using finite element method (FEM)	43
3.4.1 Regular MPP	45
3.4.1.1 Homogenous MPP	46
3.4.1.2 Inhomogeneous MPP	47
3.4.1.3 Model building	48
3.4.1.4 MPP samples simulation	48
3.4.1.5 Symmetry boundaries	49
3.4.1.6 Impedance tube	50
3.4.1.7 Material selection	53
3.4.1.8 Thermo-viscous Acoustic Physics	53
3.4.1.9 Sound source	54
3.4.1.10 Meshing setup	54
3.4.1.11 Mesh test size	55
3.4.2 Irregular MPP	60
3.4.2.1 Homogeneous MPP	61
3.4.2.2 Inhomogeneous MPP	63
3.4.3 Cross perforation	65
3.5 Models validation and experimental measurements	66
3.5.1 Sample material and model fabrication	66
3.5.2 Regular MPP samples	67
3.5.2.1 Homogeneous MPP samples	67
3.5.2.2 Inhomogeneous MPP samples	68
3.5.3 Irregular MPP samples	69
3.5.4 Cross MPP	70
3.5.5 Back air cavity	71
3.5.6 Setup and measurement	72
3.6 Summary	77
4. RESULT AND DISCUSSION	78
4.1 Introduction	78
4.2 Acoustic impedance and sound absorption coefficient results	78
4.2.1 MPP with regular hole distribution	78
4.2.1.1 Homogeneous perforation	78
4.2.1.2 Regular MPP with inhomogeneous perforation	87
4.2.2 MPP with irregular MPP hole distribution	92
4.2.2.1 Irregular MPP with homogeneous perforation	92
4.2.2.2 Irregular MPP with inhomogeneous perforation	95
4.2.3 MPP with cross perforation	97
4.3 Measurement results of sound absorption coefficient and models validation	102
4.3.1 Regular MPP with homogeneous perforation	102
4.3.2 Regular MPP of inhomogeneous perforation	102

4.3.3	Irregular MPP of inhomogeneous perforation	105
4.3.4	Cross MPP	107
4.4	Summary	109
5.	CONCLUSION AND RECOMMENDATION FOR FUTURE WORKS	110
5.1	Introduction	110
5.2	Conclusion	110
5.3	Limitation and recommendations for future work	112
	REFERENCES	113
	APPENDICES	121



LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Micro-perforated panels (MPP) absorber structure technique	35
3.1	Structural parameters of regular MPP absorber samples with homogeneous perforation	46
3.2	Structural parameters of regular MPP absorber samples with inhomogeneous perforation	48
3.3	Mesh element characterisation in the FEM	59
3.4	The structural parameters of homogeneous MPP samples with varied holes spatial distribution	61
3.5	The structural parameters of inhomogeneous MPP samples with varied holes spatial distribution	63
3.6	The structural parameters of the samples of the MPP with inhomogeneous perforation and cross pattern arrangement	65
3.7	Structural parameters of the homogeneous MPP samples	67
3.8	Structural parameters of the inhomogeneous MPP samples	68
3.9	Sstructural parameters of irregular inhomogeneous of MPP samples	70
3.10	Structural parameters of cross MPP samples	71
3.11	The equipment utilised in the experiment	73

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Use of MPP absorbers in multiple noise control applications: (a) silencer system (Tanttari et al., 2018), (b) décor systems (Herrin and Liu, 2011), (c) building acoustics (Fuchs, 2013)	2
1.2	Schematic representation of research methodology	8
2.1	Micro-perforated panel sound absorber structure (Maa, 1975)	11
2.2	Single layer MPP absorber model: (a) with a uniform cavity, (b) with trapezoidal cavity shape (Wang et al., 2010)	14
2.3	Single layer MPP absorber model with (L) shape cavity structure (Gai et al., 2017)	14
2.4	Geometry of single layer MP absorber models attached with a porous porous absorbent layer (Sakagami et al., 2011)	15
2.5	Photograph of MPP invented based on MEMS technology and its SEM micrograph (Qian et al., 2013)	18
2.6	MPP with Inhomogeneous perforation ration configuration (side view) and its electrical equivalent model (Prasetiyo et al., 2016)	19
2.7	Cross-sectional view of a single hole mode (Qian et al., 2014b)	23
2.8	MPP model absorber with different cross-sectional preformation (Ning et al., 2016)	24
2.9	Meshed model of tetrahedral configuration (Pradeep et al., 2017)	25

2.10	Schematic diagram of the perforated panel absorber model with micro-perforated partitions (Carbajo et al., 2019)	26
2.11	Picture of specimen used for perforated panel absorber (Carbajo et al., 2015)	28
2.12	Mesh of finite-element-model of perforated plates (Li et al., 2018)	30
2.13	Meshes for the examination of effects of mesh resolution around neck (Inoue and Sakuma, 2018)	30
2.14	Impedance tube schematic drawing (International Organization for Standardization, 2001)	34
3.1	Research methodology flow chart	37
3.2	Diagram of single layer MPP absorber model excited by a normal sound wave: (a) isometric view; (b) side view	39
3.3	The electrical equivalent circuit model of a single layer MPP absorber model	40
3.4	Diagram of inhomogeneous MPP: (a) isometric view and (b) side view	41
3.5	The electrical equivalent circuit model of single layer in-MPP system	42
3.6	Diagram of the regular MPPs with homogeneous perforation: (a) MPP-1, (b) MPP-2, and (c) MPP-3	47
3.7	Diagram of regular MPPs with inhomogeneous perforation: (a) iMPP-1, (b) iMPP-2, and (c) iMPP-3	48
3.8	Three-dimensional view of the simulated MPP absorber samples: (a) homogeneous model and (b) inhomogeneous model	49
3.9	The schematic graph shows a front view of the iMPP sample with	50

	the assumed symmetry boundaries	
3.10	Schematic diagram of the 3D structure in the FEM for the tube and the iMPP: (a) isometric view and (b) half-structure view	52
3.11	Representative Mesh setup for FEM: (a) single layer iMPP sample, (b) cross-sectional view of impedance tube along the symmetry boundaries, (c) view of MPP sample inside the tube and (d) close view of holes mesh	56
3.12	Normalised transfer acoustic impedance comparison between the four different sizes of mesh element: (a) real and (b) imaginary parts	59
3.13	Comparison between four normalised sound absorption coefficient of different sizes of mesh element	60
3.14	Diagram of homogeneous MPPs with different spatial distribution of holes: first column (A1-D1): regularly distributed, second column (A2 -D2): concentrated in the middle, third column (A3 -D3): distributed at the edge	62
3.15	Diagram of MPP with inhomogeneous perforation and different variation of spatial distribution of holes: first column (E1-H1): regularly distributed, second column (E2-H2): concentrated in the middle, third column (E3-H3): distributed at the edge	64
3.16	Diagram of MPP with cross perforation: (a) MPPc-1; (b) MPPc-2; (c) MPPc-3	66
3.17	Pictures of the regular MPP samples with homogeneous perforation: (1) MPP1, d: 0.5 mm, (2) MPP2, d: 0.9 mm	68
3.18	Pictures of the regular MPP samples with inhomogeneous	69

	perforation: (1) i-MPP1, (2) i-MPP2, (3) i-MPP3	
3.19	Pictures of the irregular MPP samples with inhomogeneous perforation: (1) i-MPP1, (2) i-MPP2, (3) i-MPP3	70
3.20	Pictures of the MPP samples with cross perforation	71
3.21	Pictures of the cylindrical cavity case	72
3.22	Picture of the impedance tube holder with the MPP sample inside	74
3.23	Calibrate the microphone by the calibrator	75
3.24	Photon+ analyser	75
3.25	Schematic diagram for impedance tube test setup	76
3.26	Picture of the experimental setup	77
4.1	An overview of the simulation predicted results by FEM of the normalised transfer acoustic impedance real, imaginary, and absolute parts for a single layer MPP with homogeneous perforation (MPP-3): $d = 0.9$ mm, $p = 1.70\%$, $t = 1$ mm and cavity depth, $D = 10$ mm	79
4.2	An overview of the simulation predicted results by FEM of normalised transfer acoustic impedance real, imaginary, and absolute parts of the back air cavity for the MPP-3 model: $d = 0.9$ mm, $p = 1.70\%$, $t = 1$ mm and cavity depth, $D = 10$ mm	80
4.3	Comparison of the absorption coefficient from FEM and ECM for regular MPP with homogeneous perforation (Figure 3.6, samples listed in Table 3.1): (a) MPP-1, (b) MPP-2, (c) MPP-3, cavity depth $D = 10$ mm	82
4.4	Visualized sound pressure fields distribution through the MPP hole for regular single layer MPP with homogenous perforation (MPP-3):	85

- $d = 0.9$ mm, $p = 1.70$ %, $t = 1$ mm, $D1 = 10$ mm, sample diameter = 33 mm: (a) $f=500$ Hz, (b) $f=1000$ Hz, (c) $f= 2000$ Hz
- 4.5 Cross-sectional overview of the axial velocity component distribution with streamlines, for the single layer of homogenous of MPP: $d = 0.9$ mm, $p = 1.70\%$, $t = 1$ mm, $D1 = 10$ mm, diameter of sample = 33 mm: (a) $f = 500$ Hz, (b) $f = 1000$ Hz, (c) $f = 2000$ Hz 86
- 4.6 Comparison of normalised transfer acoustic impedance, real part between FE and the EC results for a regular MPP with inhomogeneous perforation: (a) iMPP-1: $d_1 = 0.9$ mm, $p_1 = 1.76\%$, $t = 1$ mm $d_2 = 0.5$ mm, $p_2 = 0.40$ %, (b) iMPP-2: $d_1 = 0.9$ mm, $p_1 = 3.97\%$, $d_2 = 0.4$ mm, $p_2 = 1.49$ % $t = 2$, (c) iMPP-3: $d_1 = 0.9$ mm, $p_2 = 0.60\%$, $d_2 = 0.4$ mm, $p_2 = 3.00\%$, $t = 1$ mm, cavity depth for all models : $D = 10$ mm 86
- 4.7 Comparison of normalised transfer acoustic impedance, imaginary part between FE and the AM results for a regular MPP with inhomogeneous perforation: (a) iMPP-1: $d_1 = 0.9$ mm, $p_1 = 1.76\%$, $t = 1$ mm $d_2 = 0.5$ mm, $p_2 = 0.40\%$, (b) iMPP-2: $d_1 = 0.9$ mm, $p_1 = 3.97\%$, $d_2 = 0.4$ mm, $p_2 = 1.49\%$ $t = 2$, (c) iMPP-3: $d_1 = 0.9$ mm, $p_2 = 0.60\%$, $d_2 = 0.4$ mm, $p_2 = 3.00\%$, $t = 1$ mm, cavity depth is $D = 10$ mm 89
- 4.8 Comparison of the normalised absorption coefficient between FE results and EC results for regular MPP with inhomogeneous perforation: (a) iMPP-1: $d_1 = 0.9$ mm, $p_1 = 1.76\%$, $t = 1$ mm $d_2 = 0.5$ mm, $p_2 = 0.40\%$, (b) iMPP-2: $d_1 = 0.9$ mm, $p_1 = 3.97\%$, $d_2 = 0.4$ mm, 91

	$p_2 = 1.49\%$ $t = 2$, (c) iMPP-3: $d_1 = 0.9$ mm, $p_2 = 0.60\%$, $d_2 = 0.4$ mm, $p_2 = 3.00\%$, $t = 1$ mm, cavity depth $D = 10$ mm	
4.9	Results of simulation presenting the effect of holes distribution on the normalised sound absorption coefficient of irregular MPPs with homogeneous perforation and uniform cavity depth of $D = 10$ mm, panel thickness, $t = 1$ mm: (a) group A, ($d_1 = 0.5$, $N = 3$), (b) group B, ($d_2 = 0.5$, $N = 7$), (c) group C, ($d_3 = 0.5$, $N = 14$), and (d) group D, ($d_4 = 0.5$, $N = 28$)	94
4.10	Results of FE simulation presenting the effect of holes distribution on the normalised sound absorption coefficient of irregular MPPs with inhomogeneous perforation and uniform cavity depth of $D = 10$ mm, panel thickness, $t = 1$ mm: (a) group A, $d_1 = 0.8$ mm, $d_2 = 0.5$ mm, $N_1 = 3$, $N_2 = 34$, (b) group B, $d_1 = 0.8$ mm, $d_2 = 0.5$ mm, $N_1 = 7$, $N_2 = 34$, (c) group C, $d_1 = 0.8$ mm, $d_2 = 0.5$ mm, $N_1 = 14$, $N_2 = 34$, and (d) group D, $d_1 = 0.8$ mm, $d_2 = 0.5$ mm, $N_1 = 28$, $N_2 = 34$	96
4.11	Result of simulation displaying the effect of cross hole distribution on the normalised sound absorption coefficient for the SL-MPP absorber model with uniform cavity depth of $D = 10$ mm, $t = 2$ mm: (a) MPP _{c-1} $d_1 = 0.9$ mm, $d_2 = 0.5$ mm, $p_1 = 2.026\%$, $p_2 = 1.04\%$, MPP _{c-2} , (b) $d_1 = 0.8$ mm, $d_2 = 0.4$ mm, $p_1 = 1.06\%$, $p_2 = 0.79\%$, MPP _{c-3} , (c) $d_1 = 0.8$ mm, $d_2 = 0.4$ mm, $p_1 = 2.13\%$, $p_2 = 0.53\%$	97
4.12	(a) MPP _{c-1} , (b) iMPP-1, (c) comparison of the absorption coefficient between the analytical (ECM) and simulated (FEM) results for SL-MPP model with cross hole distribution (MPP _{c-1}) and also with SL-	99

	iMPP model, cavity depth $D = 10$, $t = 2$ mm, $d_1 = 0.9$ mm, $d_2 = 0.5$ mm, $p_1 = 2.026\%$, $p_2 = 1.04\%$	
4.13	(a) MPP _{c-2} , (b) iMPP-2, (c) Comparison of the absorption coefficient between the analytical (ECM) and simulated (FEM) results for SL-MPP model with cross hole distribution (MPP _{c-2}) and also with SL-iMPP model, cavity depth $D = 10$, $t = 2$ mm, $d_1 = 0.8$ mm, $d_2 = 0.4$ mm, $p_1 = 1.0\%$, $p_2 = 0.79\%$	100
4.14	(a) MPP _{c-3} , (b) iMPP-3, (c) Comparison of the absorption coefficient between the analytical (ECM) and simulated (FEM) results for SL-MPP model with cross hole distribution (MPP _{c-3}) and also with SL-iMPP model, cavity depth $D = 10$, $t = 2$ mm, $d_1 = 0.8$ mm, $d_2 = 0.4$ mm, $p_1 = 2.13\%$, $p_2 = 0.53\%$	101
4.15	Comparison of the normalised absorption coefficient between the FEM results and measured data for regular MPP samples with homogeneous perforation, cavity depth: $D = 10$ mm (a) MPP-1, $d = 0.5$ mm, $p = 0.76\%$, (b) MPP-2, $d = 0.9$ mm, $p = 0.95\%$	103
4.16	Comparison of the normalised absorption coefficient between the FEM data, EC data and measured data for regular MPP samples with inhomogeneous perforation and uniform cavity depth, $D = 10$ mm: (a) iMPP-1, $d_1 = 0.7$ mm, $d_2 = 0.5$ mm, $N = 62$ (b) iMPP-2, $d_1 = 0.7$ mm, $d_2 = 0.5$ mm, $N = 62$, (c) iMPP-3 $d_1 = 0.7$ mm, $d_2 = 0.5$ mm, $N = 62$	104
4.17	Comparison of the normalised absorption coefficient between the FEM data and measured data for irregular MPP samples with	106

uniform cavity depth, $D = 10$ mm: (a) sample iMPP-1, $d_1 = 0.9$ mm, $d_2 = 0.5$ mm, (b) sample iMPP-2, $d_1 = 0.7$ mm, $d_2 = 0.5$ (c) sample iMPP-3 $d_1 = 0.7$ mm, $d_2 = 0.5$ mm

- 4.18 Comparison of the absorption coefficient between the FEM data and measured data for cross MPP models: (a) sample MPPc-1: $d_1 = 0.9$ mm, $d_2 = 0.5$ mm, $p_1 = 2.02\%$, $p_2 = 1.04\%$, (b) sample MPPc-2: $d_1 = 0.8$ mm, $d_2 = 0.4$ mm, $p_1 = 1.06\%$, $p_2 = 0.79\%$ (c) sample MPPc-3: $d_1 = 0.8$ mm, $d_2 = 0.4$ mm, $p_1 = 2.13\%$, $p_2 = 0.53\%$ 108



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

A_h	-	The total hole area
A_s	-	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)
d_i	-	The tube inner diameter of
d_o	-	The tube outer diameter
f	-	Frequency, (Hz)
f_{max}	-	The highest computed frequency
I	-	Unit matrix.
$\text{Imag}(Z)$	-	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
N_1	-	Number of holes in left hand sub-MPP
N_2	-	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
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 = $2 \pi f$ [rad/s]
μ_B	-	The bulk viscosity describes losses due to compressibility
λ	-	The wavelength
ρ	-	Air density (kg/m ³)

