DEVELOPMENT OF BIODEGRADABLE COMPOSITE MICRO-PERFORATED PANEL MADE FROM NATURAL FIBRE COMPOSITES WITH EVALUATION OF ITS ACOUSTIC AND MECHANICAL PROPERTIES

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To my dear supervisor,

Associate Professor Dr. Musli Nizam Bin Yahya

To my dear co-supervisor,

Associate Professor Dr. Nazli Bin Che Din

To my beloved parents,

Chin Nyuk Kong and Elizabeth Villegas

and to all my family and friends.

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ABSTRACT

Micro-perforated panel (MPP) has been widely considered as a promising alternative for sound absorption purposes. Plenty of research has been done to improve the sound absorption of MPP but no specific work highlights the material structure effect towards its sound absorption performance. MPP is mostly made from metallic or plastic materials which does not exhibits any pores or tortuous structure and therefore, material structure issue is often being eliminated from analysis. In order to study the material structure effect, alternative material must be used to fabricate MPP. Numerous research found that natural fibre possesses excellent sound absorption properties due to its porous and tortuous structure. Yet, natural fibre has low tolerance towards mechanical processing and thus binder must be incorporated to overcome this shortcoming. This thesis basically describes the development process of biodegradable composite micro-perforated panel (BC-MPP) made from natural fibre (kenaf, wood, and coconut) and polylactic acid (PLA) composites. BC-MPP samples were fabricated with different material composition percentage of natural fibre and PLA. The effect of material composition percentage, perforation ratio, perforation diameter, and air cavity thickness were investigated. The effect of material structure towards the sound absorption performance of BC-MPP sample was studied. It has been found that existence of pores and tortuous structure can indeed influence the sound absorption performance of BC-MPP sample. The sound absorption performance of BC-MPP sample was compared to conventional MPP and it has been found that BC-MPP possessed better sound absorption performance courtesy to its porous and tortuous structure. BC-MPP sample also possessed better tensile strength compared to common sound absorption panel such as medium density fibreboard, hardboard, commercial ceiling board, and plywood.

ABSTRAK

Panel berlelubang mikro (MPP) dilihat sebagai alternatif yang cerah untuk tujuan penyerapan bunyi. Banyak kajian yang telah dilakukan untuk menambah baik prestasi penyerapan bunyi MPP tetapi tiada kajian tertentu yang menerangkan tentang kesan struktur bahan terhadap prestasi penyerapan bunyi MPP. MPP selalunya diperbuat daripada bahan logam ataupun plastik yang tidak mempunyai struktur liang dan berliku maka kesan struktur bahan sering diabaikan dalam analisis. Untuk menyelidik tentang kesan struktur bahan, bahan alternatif harus digunakan untuk menghasilkan MPP. Berjebah kajian yang menunjukkan bahawa gentian semula jadi mempunyai ciri-ciri penyerapan bunyi yang sangat baik disebabkan strukturnya yang liang dan berliku. Tetapi, gentian semula jadi tidak mampu mengharungi sebarang proses mekanikal maka pengikat perlu digunakan untuk mengatasi kelemahan ini. Tesis ini memerihalkan tentang proses perkembangan komposit biodegradasi panel berlelubang mikro diperbuat daripada komposit gentian semula jadi (kenaf, kayu, dan kelapa) dan asid polilaktik (PLA). Sampel BC-MPP dihasilkan dengan peratus komposisi gentian semula jadi dan PLA yang berbeza. Kesan perbezaan peratus komposisi bahan, nisbah penebukan, diameter lubang yang ditebuk, dan ketebalan rongga udara terhadap prestasi penyerapan bunyi sampel BC-MPP telah dikaji. Kesan struktur bahan terhadap prestasi penyerapan bunyi sampel BC-MPP juga diteroka. Kajian ini menunjukkan bahawa struktur liang dan berliku boleh mempengaruhi prestasi penyerapan bunyi sampel BC-MPP. Sampel BC-MPP menunjukkan prestasi penyerapan bunyi yang lebih baik berbanding dengan MPP yang biasa kerana wujudnya struktur liang dan berliku. Sample BC-MPP juga menunjukkan kekuatan tegangan yang lebih baik berbanding dengan panel penyerap bunyi yang biasa seperti papan gentian ketumpatan sederhana, papan gentian keras, papan siling dagangan, dan papan lapis.

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LIST OF SYMBOLS AND ABBREVIATIONS

$\%_{NF}$	-	Composition percentage of natural fibre
$\%_{PLA}$	-	Composition percentage of polylactic acid resin
A	-	Amplitude
a	-	Radius of neck or hole
A_0	-	Reference surface area
A_a	-	Area
A_s	-	Area of surface covered the sound source entirely
b	-	Width
c	-	Speed of sound wave
c_{sf}	-	Shape factor
C_1	-	Coefficient for metallic micro-perforated panel
C_2	-	Coefficient for non-metallic micro-perforated panel
D	-	Air cavity thickness behind the panel
d	-	Diameter of perforated hole
d_{IT}	-	Inner diameter of the impedance measurement tube
E_a	-	Absorbed sound wave energy
E_i	-	Incident sound wave energy
E_r	-	Reflected sound wave energy
E_t	-	Transmitted sound wave energy
f	-	Frequency of sound
f_L	-	Lower frequency limit
h	-	Thickness of tensile and flexural test sample
H_1	-	Transfer function of incident sound wave
H_{12}	-	Combined transfer function
H_2	-	Transfer function of reflected sound wave
I	-	Sound intensity
J_0	-	Zeroth order of Bessel function

J_1 - First order of Bessel function
k_0 - Wave number in air
k_{mp} - Coefficient of mixing process (according to specification of mixing machine used)
l - Length of neck
L - Length
l_a - Sound intensity absorbed by material
LA_{eq} - Recommended sound pressure level
LA_{max} - Maximum sound pressure level
l_b - Sound intensity from source
L_p - Sound pressure level
L_w - Sound power level
m_c - Mass of composite material
m_{cp} - Amount of composite pellets required
m_i - Mass of individual material
p - Perforation ratio
P - Power of sound wave
p_0 - Sound pressure
P_I - Magnitude of incident sound wave
P_o - Reference sound power
P_R - Magnitude of reflected sound wave
r - Shoulder radius
R - Sound reflection coefficient
r_d - Distance from the centre of sound source
R_{MPP} - Acoustic resistance
s - Length of separation between two microphones
t - Thickness
T - Time
v - Velocity of particle
V - Volume of cavity
V_{chc} - Volume of circular hollow cavity
V_{mc} - Volume of mixing chamber
w - Density of sound energy
$W_{apparent}$ - Apparent weight of porosity test sample

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