CHARACTERISTICS OF DEVELOPED FLEXIBLE POLYURETHANE FOAMS REINFORCED WITH COCONUT COIR FIBRES AND RECYCLED TYRES

CHAN WEN SHAN

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Universiti Tun Hussein Onn Malaysia

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“Special dedicated to my beloved parent and my sibling who always gave me support and encouragement”

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ABSTRACT

Flexible Polyurethane (PU) foam is generally used in seat cushions of automotive seating for comfort and supporting the occupants. However, due to the demand for more comfortable compartment; seat cushions are now designed for better riding comfort and acoustic absorption which linked to the damping of foam. Incorporated treated coir fibres (F) and tyre particles (P) into polymeric material had improved the damping and strength of the material. In this research, flexible PU foams were reinforced with two fillers for the purpose of higher damping property and improve the mechanical strength. Five samples with 2.5wt% of filler loading were developed. The damping of samples was measured on sound absorption and vibration transmissibility test that generated at 1mm, 1.5mm, 0.1g, and 0.15g base excitation while their mechanical properties were examined through compression, tear resistance, and compression set. The morphology of samples was also observed by SEM in this research. The results showed that the foam composites produced have smaller cell size, in which the smallest was 840µm compared to 1290µm obtained in pure PU foam. The mechanical properties revealed that the strength of flexible PU foam increased with added treated coir fibres and recycled tyres. The best properties were shown in PU+2.5wt%(50F50P) which increased by 10.78% on the compressive modulus, 9.33% on the compressive strength, 14.49% on the static energy absorption, and 3.76% on the tear strength compared to pure PU foam. The sound absorption and vibration damping of the developed foams showed that more energy were absorbed and dissipated by these foams after fillers added. The PU+2.5wt%(80P20F) and PU+2.5wt%F presented an excellent sound absorption characteristics at 20mm and 40mm thickness, respectively, whereas PU+2.5wt%P, PU+2.5wt%(80P20F), and PU+2.5wt%(80F20P) showed higher vibration damping from the transmissibility test.

ABSTRAK

Pada amnya, *Flexible Polyurethane (PU)* berbusa diguna dalam kusyen tempat duduk kenderaan untuk memberi keselesaan dan menanggung penggunanya. Namun, atas permintaan pengguna supaya bahagian dalaman menjadi lebih selesa, kusyen tempat duduk kenderaan kini di rekabentuk untuk keselesaan dan penyerapan akustik yang lebih baik, dimana ianya berhubung kait dengan penyerapan pada bahan yang berbusa. Campuran sabut kelapa dirawat (F) dan serbuk tayar (P) ke dalam bahan polimer meningkatkan penyerapan dan kekuatan bahan. Dalam kajian ini, *flexible PU* berbusa diperkukuh dengan dua pengisian bagi tujuan meningkatkan penyerapan dan kekuatan mekanikal bahan. Lima sampel kajian dengan 2.5wt% pengisian telah dihasilkan. Penyerapan bahan komposit diukur dengan ujian penyerapan bunyi dan ujian kebolehpindahan getaran yang dilakukan pada 1mm, 1.5mm, 0.1g, dan 0.15g yang diuja pada tapak, manakala sifat-sifat mekanikal pula diperolehi melalui ujian seperti mampatan, rintangan koyak, dan set mampatan. Morfologi komposit pula diperolehi dari *SEM* dalam kajian ini. Keputusan ujian menunjukkan bahawa komposit berbusa yang dihasilkan mempunyai sel bersaiz lebih kecil, di mana yang paling kecil adalah 840μm berbanding dengan 1290μm yang diperolehi dari *PU* berbusa yang tulen. Sifat-sifat mekanikal menunjukkan bahawa kekuatan *flexible PU* berbusa meningkat dengan campuran sabut kelapa dirawat dan serbuk tayar kitar semula. Sifat-sifat yang terbaik ditunjukkan pada PU+2.5wt%(50F50P) dan ianya meningkat sebanyak 10.78% pada modulus mampatan, 9.33% pada kekuatan mampatan, 14.49% pada penyerapan tenaga statik, dan 3.76% pada kekuatan koyak berbanding dengan *PU* berbusa yang tulen. Penyerapan bunyi dan serapan getaran bahan yang di hasilkan menunjukkan bahawa ianya meningkat apabila bahan berbusa dicampur dengan pengisian, iaitu PU+2.5wt%(80P20F) dan PU+2.5wt%F dimana ianya boleh menyerap bunyi dengan baik pada ketebalan 20mm dan 40mm, manakala PU+2.5wt%P, PU+2.5wt%(80P20F), dan PU+2.5wt%(80F20P) pula boleh menyerap getaran dengan baik dalam ujian kebolehpindahan.

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LIST OF SYMBOLS

E'	-	Storage modulus
E"	-	Loss modulus
Tan δ	-	damping factor
σ	-	stress
ε	-	strain
ρ, D	-	Density
F_k	-	Elastic force
k, K_1. K_2, K_c	-	stiffness
k_3, k_5	-	Nonlinear stiffness
x, z	-	Displacement in uniaxial compression
$\Gamma(t\text{-}\tau)$	-	Material's relaxation kernel or viscoelastic strain-impulse response
t	-	Time
τ	-	Time variable
E	-	Instantaneous modulus
$D^{\beta}\sigma(t)$	-	Fractional derivative operator of the stress σ(t)
β, E_s,E_0, E	-	Viscoelastic parameters (equation 2.3)
$c\dot{z}$	-	Linear viscous damping in uniaxial compression
c, C_1, C_2, C_c	-	Damping coefficient or damping constant
ξ	-	Damping ratio
X_0, Y_0, Z_0	-	Dimension of cubic cushion model
A	-	Contact area
D	-	Original cushion thickness
W, M, m	-	Total mass or total riding mass
ω_n	-	Natural frequency
ω	-	Forced frequency

ω_b	-	Base frequency
x, X	-	Passenger or mass motion (output)
y, Y	-	Base motion (Input)
Θ_1, Θ_2	-	Phase angle
$m\ddot{x}$	-	Inertia force
$c(\dot{x} - \dot{y})$	-	Damping force caused by motion input to output
$k(x - y)$	-	Restoring or elastic force
r	-	Frequency ratio
K_x, K_y, K_z	-	Stiffness in x, y, or z axis
S	-	Structural coefficient
J	-	Energy
V	-	Volume
T	-	Thickness of foam when in tear resistance test
C_t	-	Compression set (measured in thickness) in percentage
t_o, t_f	-	Original thickness and final thickness
α	-	Sound absorption coefficient or viscoelastic parameter
T_r	-	Transmissibility
B	-	Damping parameter (equation 7.3)
NCO	-	Reactive isocyanate group (-N=C=O)
R	-	Reactive group from isocyanate
R’	-	Reactive group from polyol
pH	-	Activity of the (solvated) hydrogen ion
C_nH2n	-	Hydrocarbon chemical group
C_nH_{2n-1}	-	Hydrocarbyls chemical group
$(CH_2O)_n$	-	Group of natural saccharine
n	-	1, 2, 3 …
Y_1, Y_2, Y_3, Y_4	-	Displacement amplitude (Figure 7.5 or equation 7.3)
β	-	logarithmic decrement (equation 7.3)
i	-	1, 2, 3 …

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LIST OF ABBREVIATIONS

PU	-	Polyurethane
F	-	Treated Coir Fibres
P	-	Recycled Tyre Particles
PET	-	Polyethylene Terephthalate
US	-	United States
wt.	-	weight
SEM	-	Scanning Electron Microscopy
XRF	-	X-Ray Fluorescence
TGA	-	Thermogravimetric Analysis
ASTM	-	American Society for Testing and Materials
TDI	-	Toluene Diisocyanate
MDI	-	Methylene Diphenyl Diisocyanate
UV	-	Ultraviolet
CFD	-	Compression Force Deflection
Php	-	Part By Hundred Parts Of Polyol
T	-	Top
B	-	Bottom
MT	-	Mid-Top
MB	-	Mid-Bottom
CNT	-	Carbon Nanotubes
SBR	-	Styrene-Butadience Rubber
BR	-	Butadience Rubber
IIR	-	Butyl Rubber
DMA	-	Dyanamic Mechanical Analysis
DMTA	-	Dynamic Mechanical Thermal Analysis
NR	-	Natural Rubber
WGRT	-	Waste Ground Rubber Tire

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