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## The Effect of Sound Absorption Coefficient of Particle Addition to Polyurethane Matrix Composites

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### ABSTRACT

The primary goal of this research study is to enhance acoustic properties of polyurethane in particle reinforcement composites. This study is done for studying acoustic properties of polyurethane in wood particle reinforcement composites. Polyurethane is the potential polymer to be used according to previous researches' study. Polyurethane is one of higher sound-absorbing materials. It offers another interesting possibility based on its acoustic property. Besides that, polyurethane is an organic polymer which is weather resistant, heat and cold resistant, and has excellent acoustic property. Polyurethane-based binders are used in composite wood products to permanently glue organic materials into wood polymer composite. The particle reinforcement composites in this study are made of wood particle and polymer. The used raw materials of particle reinforcement composites are natural waste wood particle. The particle as reinforcement are biodegradability, convenient renewability and environmentally friendly. The wood particle have supreme benefits such as good thermal resistance, high sound absorbing efficiency (sound absorption coefficient-acoustic properties), higher resistant to fracture, and more shatter resistant. The objectives of this paper are to utilize the advantages of polymer in polymer matrix composites and to study sound absorption and noise reduction abilities of polymer matrix composites. Six samples were tested through two-microphone method to obtain each sound absorption coefficient respectively. The neat polyurethane foams and polyurethane composites were prepared based on different weight ratio composition. The density and porosity of the testing samples play important role in sound absorption. All testing samples were examined through optical microscope and scanning electron microscope to observe and determine pore size of the samples. The tested frequency range was between 500Hz-6000Hz. Each sample has shown approximately same sound absorption coefficient at different frequency. The polyurethane matrix composites have a small amount different of sound absorption coefficient compare with their neat polyurethane foam. This study is conducted by using two-microphone method according ASTM E 1050. From the results of sound absorption analysis, the polyurethane foam of composition of 56.5 wt% diphenylmethane diisocyanate (MDI) with 43.5 wt% polyester polyol has higher sound absorption coefficient compare to other composition of polyurethane foams and polyurethane matrix composites. The development of polyurethane foam still can continuously on going to concentrate on treated wood particle. At the same time, other interesting parameters could be included in this study for further analysis.

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## INTRODUCTION

Polyurethane is used in a wide range as sound absorption or insulation and vibration dampening. Flexible polyurethane foams are widely used in noise quieting of automobiles, machinery and other industrial applications. (Alton Everest, F., 2009) The combination of polyurethane with wood particle as wood polymer composite will be applied and installed inside car engine hood to absorb engine block's noise.

### Objectives:

The objectives of this research are:

- i. To utilize the advantages of polymer in polymer matrix composites
- ii. To study sound absorption and noise reduction abilities of polymer matrix composites

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## MATERIALS AND METHODS

The polyurethane foam is prepared by adding diphenylmethane diisocyanate (MDI), polyester polyol, epoxy resin A, and epoxy resin B together accordingly. The one-shot free rising method is used to obtain polyurethane foam and polyurethane matrix composite. A wood particle is added based on weight percentage, wt% of each sample.

### 3.1 Materials:

#### Raw materials:

- a) Diphenylmethane Diisocyanate (MDI)
- b) Polyester Polyol
- c) Epoxy Resin A
- d) Epoxy Resin B
- e) Wood particle

### 3.2 Preparation of polyurethane foam and polyurethane matrix composite:

#### Experiment for polyurethane foams:

- I. Weighed out the polyester polyol using electronic balance
- II. Follow by adding in the diphenylmethane diisocyanate
- III. Finally with the epoxy resin A and B respectively
- IV. Stirred the mixture evenly for 10seconds
- V. The sample is left for curing
- VI. The polyurethane foam is conditioned at room temperature for one day before further characteristics
- VII. The resulting foam is to be cut into cylinder size for density testing, pore size estimation and lastly impedance tube testing to determine sound absorption coefficient

#### Experiment for polyurethane matrix composites:

- I. Weighed out wood particle
- II. Weighed out polyester polyol using electronic balance
- III. Follow by adding in the diphenylmethane diisocyanate
- VIII. Finally with the epoxy resin A and B respectively
- IV. Stirred the mixture evenly for 10seconds
- V. Add wood particle immediately after 15seconds
- VI. The sample is left for curing
- VII. The polyurethane foam is conditioned at room temperature for one day before further characteristics
- VIII. The resulting foam is to be cut into cylinder size for density testing, pore size estimation and lastly impedance tube testing to determine sound absorption coefficient

### 3.3 Testing Method:

#### 3.3.1 Optical Microscope and Scanning Electron Microscope:

Optical Microscope and Scanning Electron Microscope are used to capture the image of pore size of different polyurethane foam. The dimension of pore size is measured from each captured image. The optical microscope is used to observe the respective captured image to spot the size of open celled of the polyurethane foam. The pore size of each part polyurethane foam is measured to determine the homogenous structure of the polyurethane foam.

#### 3.3.2 Impedance Tube:

The two-microphone method is used to determine the sound absorption coefficient by using sound waves to strike the testing samples. The diameter of the testing samples is 0.025m to fill in the cross section of the impedance tube. The experiment is set up according to two standards for measurement of acoustical properties of materials (measuring sound absorption of polyurethane foam and polyurethane matrix composites): ASTM E 1050 (ASTM E1050, 2008) (developed by The American Society for Testing and Materials) and ISO 10534-2 (developed by International Standard Organization).

##### 3.3.2.1 Sound Absorption Coefficient, $\alpha$ :

To obtain sound absorption coefficient of polyurethane foam and polyurethane matrix composite,  $\alpha$ , following definitions (ASTM E1050, 2008) are defined.

$H$  : transfer function of the two microphone signals corrected for microphone response mismatch

$H^-$  : measured transfer function of the two microphone signals

$H_I, H_{II}$  : calibration transfer functions for the microphones in the standard and switched configurations, respectively

$H^{-1}c$  : complex microphone calibration factor

$K$  : equal  $2\pi f/c$ ; wave number, m<sup>-1</sup>

$s$  : centre-to-center spacing between microphones, m

$c$  : speed of sound, m/s

$l$  : distance from the test sample to the centre of the nearest microphone, m

Meanwhile, the working frequency range (Harris, C.M., editor, 1988) is:

$$f_l < f < f_u$$

where:

$f$  = operating frequency, hertz,

$f_l$  = lower working frequency of the tube, hertz, and

$f_u$  = upper working frequency of the tube, hertz

Furthermore, the upper frequency limit (Rayleigh, J.W.S., 1896) is defined as follows:

$$f_u < K \times c / d$$

where:

$f_u$  = upper frequency limit, hertz,

$c$  = speed of sound in the tube, m/s,

$d$  = diameter of the tube, m, and

$K = 0.586$

Sound absorption coefficient is determined by calculating using equations (ASTM E1050, 2008; Chung, J.Y. and D.A. Blaser, 1980) as follows:

$$\alpha = 1 - |R|^2$$

$$= 1 - R_r^2 - R_i^2$$

where:

$R_r$  and  $R_i$ : the impulsive responses corresponding to the reflected wave evaluated at the first and the second microphone locations, respectively[4]

$$R_r = \{2H_r \cos [k(2l+s)] - \cos(2kl) - (H_r^2 + H_i^2) \cos [2k(l+s)]\} / D$$

$$R_i = \{2H_i \sin [k(2l+s)] - \sin(2kl) - (H_r^2 + H_i^2) \sin [2k(l+s)]\} / D$$

$$D = 1 + H_r^2 + H_i^2 - 2[H_r \cos(ks) + H_i \sin(ks)]$$

$H_r$  and  $H_i$ : the impulsive responses corresponding to the incident and the reflected waves, respectively, evaluated between the two microphone locations (Rayleigh, J.W.S., 1896)

$$H_r = (1/|H_c^-|) (H_r^- \cos \phi_c + H_i^- \sin \phi_c)$$

$$H_i = (1/|H_c^-|) (H_i^- \cos \phi_c - H_r^- \sin \phi_c)$$

$$\phi_c = (1/2) \tan^{-1} [(H_i^- H_r^{-11} + H_r^- H_i^{-11}) / (H_r^- H_r^{-11} - H_i^- H_i^{-11})]$$

$$|H_c^-| = \{[(H_r^{-11})^2 + (H_i^{-11})^2] [(H_r^{-11})^2 + (H_i^{-11})^2]\}^{(1/4)}$$

$$k = 2\pi f / c$$

In this paper,

$$s = 0.0245 \text{ m}$$

$$c = 346 \text{ m/s}$$

$$l = 0.052 \text{ m}$$

$$f_l < f < f_u = 500 \text{ Hz} \leq f \leq 6000 \text{ Hz}$$

## RESULTS AND DISCUSSIONS

The neat polyurethane foams and polyurethane composites were prepared based on different weight ratio composition. Table 1 shows the composition for each foams and composites.

**Table 1:** Formulation for preparation of neat polyurethane foams and polyurethane composites.

Samples	Diphenyl-methane Diisocyanate		Polyester Polyol		Wood Particle	
	g	wt%	g	wt%	g	wt%
1	5.0	50	5.0	50	0	0
2	6.5	56.5	5.0	43.5	0	0
3	7.0	58.3	5.0	41.7	0	0
4	6.5	56.2	5.0	43.3	0.06	0.5
5	6.5	55.9	5.0	43.0	0.12	1.0
6	6.5	55.7	5.0	42.8	0.18	1.5



**Fig. 1:** Image of Sample 2, 3 and 6 after cut into specific dimension.

#### 4.1 Density:

The dimensions, mass, volume and density of the testing samples are shown in Table 2 and Table 3 respectively. The density plays important role in sound absorption. High density of samples will show the increase of sound absorption coefficient in middle and high frequency (Koizumi, T., 2002).

**Table 2:** Dimension of each neat polyurethane foams and polyurethane composites.

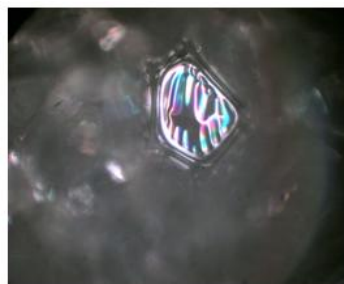
Samples	Diameter, m	Thickness, m
1	$25 \times 10^{-3}$	$9 \times 10^{-3}$
2	$25 \times 10^{-3}$	$9 \times 10^{-3}$
3	$25 \times 10^{-3}$	$9 \times 10^{-3}$
4	$25 \times 10^{-3}$	$9 \times 10^{-3}$
5	$25 \times 10^{-3}$	$9 \times 10^{-3}$
6	$25 \times 10^{-3}$	$9 \times 10^{-3}$

**Table 3:** Mass, volume and density of each sample.

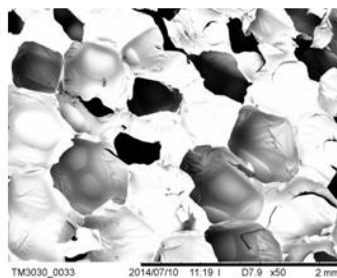
Samples	Mass, kg	Volume, m <sup>3</sup>	Density, kg/m <sup>3</sup>
1	$2.20 \times 10^{-4}$	$4.418 \times 10^{-6}$	49.8
2	$2.31 \times 10^{-4}$	$4.418 \times 10^{-6}$	52.3
3	$1.88 \times 10^{-4}$	$4.418 \times 10^{-6}$	42.6
4	$1.94 \times 10^{-4}$	$4.418 \times 10^{-6}$	43.9
5	$2.07 \times 10^{-4}$	$4.418 \times 10^{-6}$	46.9
6	$2.31 \times 10^{-4}$	$4.418 \times 10^{-6}$	52.3

#### 4.2 Porosity:

All testing samples were examined through optical microscope and scanning electron microscope to observe and determine pore size of the samples. Pores are one of important factors that influence dissipation of sound by friction. Sound energy get damped when pass through enough open pores. (Hoda, S., Seddeq, 2009) The pore size is ranging from around  $0.5 \times 10^{-3}$ m to  $0.8 \times 10^{-3}$ m for Sample 2, see Figure 3.



**Fig. 2:** Optical microscope image of pore size of Sample 1 (neat polyurethane foam).



**Fig. 3:** Scanning electron microscope image of pore size of Sample 2 (neat polyurethane foam).

### 4.3 Sound Absorption:

The tested frequency range was between 500Hz-6000Hz. The sound absorption of each sample was tested by using impedance tube (two-microphone method) (ASTM E1050, 2008).

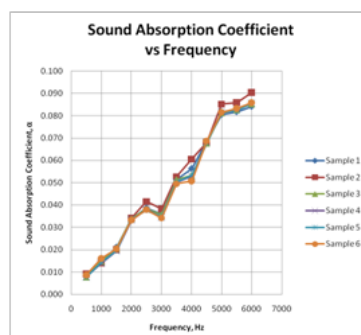
**Table 2:** Measured sound absorption coefficient of neat polyurethane foams.

Frequency, Hz	Sound Absorption Coefficient, $\alpha$		
	Samples		
	1	2	3
500	0.008	0.009	0.008
1000	0.014	0.014	0.015
1500	0.021	0.020	0.021
2000	0.034	0.034	0.034
2500	0.039	0.042	0.038
3000	0.036	0.038	0.036
3500	0.051	0.053	0.051
4000	0.056	0.061	0.053
4500	0.069	0.068	0.068
5000	0.080	0.085	0.081
5500	0.082	0.086	0.083
6000	0.084	0.090	0.085

**Table 3:** Measured sound absorption coefficient of polyurethane matrix composites.

Frequency, Hz	Sound Absorption Coefficient, $\alpha$		
	Samples		
	4	5	6
500	0.008	0.008	0.009
1000	0.014	0.014	0.016
1500	0.019	0.020	0.021
2000	0.033	0.034	0.033
2500	0.038	0.038	0.038
3000	0.034	0.035	0.034
3500	0.050	0.050	0.050
4000	0.053	0.053	0.051
4500	0.068	0.068	0.069
5000	0.082	0.082	0.082
5500	0.083	0.082	0.083
6000	0.086	0.086	0.086

Six samples were tested through two-microphone method to obtain each sound absorption coefficient respectively. Each sample has shown approximately same sound absorption coefficient at different frequency. The neat polyurethane foam that has composition of 56.5 wt% diphenylmethane diisocyanate (MDI) with 43.5 wt% polyester polyol has higher sound absorption coefficient ( $\alpha=0.09$ ) compare with other composition of polyurethane foams and polyurethane matrix composites. According to Figure 4, the foams and composites have almost same pattern of graph curve. The polyurethane matrix composites have a small amount different of sound absorption coefficient compare with their neat polyurethane foam.



**Fig. 4:** Sound Absorption Coefficient of different neat polyurethane foams and polyurethane matrix composites.

### Conclusions:

This study is conducted by using two-microphone method according ASTM E 1050. From the results of sound absorption analysis, the polyurethane foam of composition of 56.5 wt% diphenylmethane diisocyanate (MDI) with 43.5 wt% polyester polyol has higher sound absorption coefficient compare to other composition of polyurethane foams and polyurethane matrix composites. The development of polyurethane foam still can

continuously on going to concentrate on treated wood particle. At the same time, other interesting parameters could be included in this study for further analysis.

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#### ***Authors' Contribution:***

Dr. Amir Azam Khan developed the idea of using polyurethane in sound absorbing purpose and had played his important role in methodology and discussion of results.

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There is no conflict of interest.

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### REFERENCES

- Alton Everest, F., Ken, C. Pohlmann, 2009. "Master Handbook of Acoustics," New York: *The McGraw-Hill Companies, Inc*, Chapter, 1-1.
- ASTM E1050, 2008. *Standard test method for impedance and absorption of acoustical materials using a tube, two microphones, and a digital frequency analysis system*.
- Harris, C.M., editor, 1988. "Shock and Vibration Handbook," *McGraw-Hill*, Third Edition, Chapter, 21: 4-8.
- Rayleigh, J.W.S., 1896. "The Theory of Sound," *Dover Publications, Inc.*, New York, NY, 2: 161.
- Chung, J.Y. and D.A. Blaser, 1980. "Transfer Function Method of Measuring In-Duct Acoustic Properties I. Theory and II. Experiment," *Journal of the Acoustical Society of America*, 68(3): 907-921.
- Koizumi, T., N. Tsujiuchi and A Adachi, 2002. "*The Development of Sound Absorbing Materials Using Natural Bamboo Fibers, High Performance*", WIT Press.
- Hoda, S., Seddeq, 2009. "Factor Influencing Acoustic Performance of Sound Absorptive Materials", *Australian Journal of Basic and Applied Sciences*, 3(4): 4610-4617.