PREPARATION AND CHARACTERIZATION OF POLYURETHANE FILLED WASTE TYRE DUST (PU/WTD) COMPOSITE FOAM FOR NOISE ABSORPTION MEDIUM

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This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons.)

by

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Sesi Pengajian: **2016/2017 Semester 2**

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I hereby, declared this report entitled "Preparation and Characterization of Polyurethane filled Waste Tyre Dust (PU/WTD) Composite Foam for Noise Absorption Medium" is the result of my own research except as cited in references.

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Author's Name : NORAMALINA BINTI RASMI

Date : 22 June 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons). The member of the supervisory committee are as follow:

…….....

(DR. JEEFFERIE BIN ABD. RAZAK)

…….....

(DR. MOHD SUKOR BIN SALLEH)

ABSTRAK

Selama bertahun-tahun ini, pendedahan bunyi tidak diambil serius dalam perekaan alat mekanikal di dalam sesetengah aplikasi seperti peranti kenderaan, pengankutan atau mesin industri. Kebiasaannya, bunyi boleh dikawal dengan menggunakan bahan serapan seperti bahan yang berpori. Polyurethane (PU) telah dipilih sebagai bahan berpori dalam penyilidikan ini kerana ia mempunyai struktur pori yang terbentuk daripada interaksi polyol dan isocyanate. Dengan mempertimbangkan kehijauan dan kelestarian alam sekitar, serbuk sisa tayar (WTD) digunakan untuk menguatkan bahan asas polimer. Kajian ini bertujuan untuk menyediakan busa komposit PU/WTD pada pelbagai beban WTD (5, 15 and 25 wt %) dengan tempoh pengacauan yang berbeza (5, 20 dan 35 minit) sebagai media penyerapan bunyi dimana parameter penyediaan busa telah dioptimumkan berpandukan keatas keupayaan serapan bunyi meggunakan perisian reka bentuk eksperimen (DOE) dengan penggunaan dua tahap reka bentuk faktorial penuh. Kemudian, respon keatas keupayaan serapan telah dihubungkaitkan dengan morfologi busa yang diperhatikan dibawah imbasan mikroskop electron (SEM) Daripada analisis ANOVA, ia dicadangkan bahawa parameter kajian yang optima dalam penyediaan busa adalah penyediaan busa komposit yang disediakan dengan beban WTD sebanyak 25 wt % pada 5 minit tempoh pengacauan. Sementara itu, parameter paling teruk bagi penyediaan busa adalah dimiliki oleh busa yang disediakan dengan beban WTD sebanyak 25 wt % pada 35 minit tempoh pengacauan. Oleh itu, hubungkait bersama morfologi busa telah dianalisa dan ianya telah dikonklusikan bahawa busa komposit PU/WTD dengan struktur sel pori terbuka meningkatkan keupayaan serapan bunyi berbanding struktur sel pori tertutup. Walau bagaimanapun, struktur sel pori terbuka ini telah mengurangkan ketumpatan busa komposit and merendahkan kekuatan mampatan busa komposit PU/WTD disebabkan oleh kekurangan daya tahan dibawah tekanan mampatan. Di samping itu, ia telah dianalisa bahawa busa komposit dengan struktur pori yang lebih terbuka mampu menyerap lebih banyak air.

ABSTRACT

Over the years, noise exposure are not being taken seriously in designing a mechanical device in some application such as vehicle parts, transportation or industrial machine. Usually, the noise can be controlled by using an absorption material such as porous material. Polyurethane (PU) was chosen as an absorption material in this research because it has porous structure that were formed by the interaction of polyol and isocyanate. By considering the green environmental and sustainability, Waste Tyre Dust (WTD) are used to reinforce the polymeric based material. This study aim to prepare the PU/WTD composite foam at various WTD loadings (5, 15 and 25 wt %) with different stirring period (5, 20 and 35 minutes) for noise absorption medium whereby the parameter of the foam preparation had been optimized based on sound absorption coefficient using Design of Experiment (DOE) software with utilization of two level full factorial design approach. Later, response of the absorption coefficient was correlated with foam morphologies that observed under Scanning Electron Microscope (SEM). From ANOVA analysis, it was postulated that the optimized parametric study of foam preparation are the PU/WTD composite foam prepared with 25 wt % of WTD at 5 minutes of stirring period Meanwhile, the worst parameter of foam preparation are owned by PU/WTD foam that prepared with 25 wt % of WTD at 35 minutes of stirring period. Therefore, the correlation with the foam morphologies was analysed and it was concluded that PU/WTD composite foam with open pore cell structure enhance the sound absorption coefficient rather than closed cell structure. However, these open pore cell structure had reduced the density of the composite foam and decrease the compression strength of the PU foam. In addition, it was analysed that PU/WTD composite foam with more open pore structure could able to absorb more water.

DEDICATION

Dedicated for my

Mother, Junaidah Binti Mohamed

Father, Rasmi Bin Jasulidin

Amazing siblings

Honourable lecturers

Loyal friends

Much love from Noramalina

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"In the name of ALLAH, the most gracious, the most merciful"

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PU	-	Polyurethane
WTD	-	Waste Tire Dust
NVH	-	Noise, Vibration and Harshness
DOE	-	Design of Experiment
SS	-	Soft Segment
HS	-	Hard Segment
TDI	-	Toluene Diisocyanate
MDI	-	Diphenylmethane Diisocyanate
HDI	-	Hexane Diisocyanate
IPDI	-	Isopherone Diisocyanate
NDI	-	Naphthalene Diisocyanate
RHA	-	Rice Husk Ash
IIR	-	Butyl Rubber
NBR	-	Butadiene Acrylonitrile Rubber
PPG	-	Polypropylene Glycol Triol
OSHA	-	Occupational Safety and Health Administration
RLDPE	-	Recycled Low-Density Polyethylene
BAP	-	Bagasse Ash Particles
VDM	-	Viscoelastic Damping Material
Ss	-	Sliding Speed
La	-	Load

Sd	-	Sliding Distance
ASTM	-	American Society for Testing and Materials
CLC	-	Combine Loading Compression
SEM	-	Scanning Electron Microscopy
OM	-	Optical Microscopy
CB	-	Carbon Black
Min	-	Minute
wt	-	weightage

LIST OF SYMBOLS

wt %	-	Weight percentage
%	-	Percentage
°C	-	Degree Celsius
°C/min	-	Degree Celsius per minute
mm	-	Millimeter
mm/min	-	Millimeter per minute
m	-	Meter
m/s	-	Meter per second
rpm	-	Revolution per minute
in	-	Inch
Hz	-	Hertz
dB	-	Decible
SWR	-	Wave ratio
R	-	Reflection coefficient amplitude
Rn	-	Sound power reflection coefficient
α	-	Sound absorption coefficient,
A+B	-	maximum pressure of sound
A-B	-	Minimum pressure sound
κ	-	Number of factors
N	-	Newton
g	-	gram
g/Ml	-	Gram per milliliter
g/m^3	-	gram per meter cube
X_1	-	Waste tire dust loading (wt %)
X_2	-	Stirring period (minute)
ρ	-	Density
m/v	-	Mass per volume

W_y	-	Final weight of sample
W_x	-	Initial weight of sample
min^{-1}	-	minute per second
µm	-	Micro meter
x	-	Image resolution
A	-	WTD loading
B	-	Stirring period
E	-	Exponential

CHAPTER 1
INTRODUCTION

This chapter briefly explained the background of study for this project. The objective and the scope of research are also included. Besides, the project significance, thesis organization and summary of the chapter are also stated and detailed out in this chapter.

1.1 Background of Study

Over the years, noise, vibration, and harshness (NVH) are not being taken critically during the design stage, and operation of vehicles or machines in their real service condition. As the technology growth, NVH factor has turned into crucial consideration for better improvement (Happian-Smith, 2002). NVH are important especially in the application such as in industrial machine and automotive industries as it effects the user comfortability and safety. Noise can be accepted for human hearing if it was operated within their frequency range while vibration can interfere human physical comfort without sufficient damping.

Generally, the attenuation of noise and vibration can be increased by using a porous material (Zhang *et al*., 2012). Polyurethane based composite foams were chosen in the research done by Gambang and city (2013) as the porous material for noise absorption and vibration damping medium. Due to combination of two main materials namely as polyol and isocyanate, the foams were made and form a rigid or flexible foam, whereby the flexible foams are commonly consisted of open cell structure, while rigid foams consisted of closed cell structure. Back to several years ago, the polyol used in making of polyurethane are solely based on synthetic polyols such as poly (glycolide), poly (ethylene adipated) and poly (hexamethylene oxide). However, concerning to the green environmental and sustainability awareness, the polyol used in polyurethane manufacturing are already substituted with the

bio-based polyol or vegetable polyol resources. Palm oil are one of the famous raw feedstock that is used as the polyol source for the manufacturing of polyurethane foams. Palm oil could give advantages in reducing the demand for hydrocarbon-based oil towards the creation of low greenhouse gas emission. In addition, palm oil could be obtained at a very reasonable cost. This factor could contribute them to be an ideal solution for cost-saving replacement of hydrocarbon-based polyol without compromising the final product quality

Nowadays, various filler was embedded into the polyurethane based composite foams in order to optimize their related engineering properties such as mechanical and physical attributes. A study conducted by Fiorelli *et al*. (2012) had used sugarcane bagasse as the reinforcement in the polyurethane where it was included in the castor oil based polyol for particleboards production in order to enhance the resulted properties of density, absorption and swelling index, and their modulus of elasticity. By having the sugarcane bagasse filler inclusive within polyurethane, it was found that the physicomechanical properties of produced particleboards were significantly improved. The particleboard produced are resilience and extraordinary sustainable for their usage in the moist environment.

As to control the vibration in NVH, viscoelastic material possesses a higher ability to absorb more vibration effect due to its damping behavior (Sung *et al*., 2016). According to Jones (2001), damping is one of the main requirement for a good mechanical design of mechanical structures, machines, and vehicles. Rubber particles have been used in many types of research to overcome the limitation of damping behavior. The performance towards the damping is due to the nature of viscoelastic behavior where it has an ability in absorbing vibration for a better comfortability (Issa and Salem, 2013). The dramatic growth of waste tire in this age was recorded due to increasing number of vehicles on the road and over utilization of it. The increasing of waste tire has led to a negative consequence towards their disposal issue. Therefore, waste tire dust is used in the production of polyurethane based composite foams in order to improve the damping behavior in sound absorption for better control of NVH.

Thus far, there are large number of current studies on polyurethane based composite foam which specifically investigate the effect of filler type and its loading to the response

for acoustic absorption. Nevertheless, there are still no similar research was dedicated on polyurethane reinforced waste tire dust at various loading with various stirring period of composite foam preparation for noise absorption medium.

This study was conducted to see the relationship and correlation between the effects of waste tire dust filler loadings and stirring time with the noise absorption response. The correlation of the absorption performance with the foam morphologies was analyzed. In addition, other important various support testing of physical and mechanical are also conducted to understand the roles of experimental variables to the obtained findings.

The pores morphologies were observed by using the Scanning Electron Microscopy (SEM) to analyze the characteristic of noise absorption for produced PU based composite foams, with regard to their cell structure of foams. Most important, in achieving the objectives stated for this research, the design of experiment (DOE) approach using two level full factorial strategy was used in optimizing the important major response of noise absorption attributes. Last but not least, through this study, it is hoped that the developed PU/WTD composite foams could be potentially becoming as an alternative advanced materials for next generation high performance noise absorption medium.

1.2 Problem Statement

Noise is an important element that must be considered in many application especially in vehicles and transportation. Most of the vehicle parts either external or internal part are experienced with the effects of NVH exposure. External parts are more likely exhibit the noise and vibration due to tire movement (Backer *et al.*, 2016). Another major factor that also contributed such as the working system in engines, radiator vibration, and timing belt oscillation while internal part tends to affect the passenger's comfort during the vehicle motion (Heibing and Ersoy., 2011). Good comfortability is crucial for vehicle's driver during their travel as it may affect the performance of driving either in a lower or higher velocity and speed. In fact, the comfortability should be attained in whatever road condition during the movement of vehicles.

In brief explanation, noise is a type of pollution which could directly trouble the driver and also surrounding environment. Disruption from undesirable noise contributes to a poor NVH control in the automobile application. Such these disruptions tend to produce bad interference to a comfortability while driving the vehicle. According to OSHA, noise which achieve 90 dB and above are categorized as noise pollution where it have a big chance in contribution to permanent human hearing loss. Since materials are always related with the design approach, it is important to select them with careful consideration during manufacturing stage during the production of the mechanical based components. Based on previous studies, there is improvement made in selecting the good materials candidates to tackle this noise issue for an automotive and occupational application.

One of the latest study regarding the improvement of sound absorption was performed by Sung *et al*. (2016). They utilized the polymeric material to enhance the sound absorption performance. The polyurethane composite filled with magnesium hydroxide filler was developed for this purpose. A good structural materials are needed to be formed in order to achieve the desired characteristic of component functionality. As the absorption medium, porous material with homogenous pores dimension structure is necessary to be produced. Polyurethane is chosen as they possessed the porous structure for this intended purpose. As the polyol and the isocyanate material used based on petroleum oil, it contributes to a higher price of the feedstock material. This could be solved by substituting the petroleum oil with biodegradable and renewable source polymeric material. It is therefore suggested that the substitution of the petroleum oil with the palm oil polyol in producing a polyurethane foam are relevant (Pawlik and Prociak., 2012).

Nowadays, the pollutions towards the environment are getting serious. One of the pollutions comes from the burning of waste tire to the atmosphere without any proper treatment which makes the air contaminated with a black smoke (Pacheco-Torgal *et al*., 2012). As a tire waste are getting dominant with the increasing number of the vehicle, this disposal issue need to be tackled in smart ways. Usage of waste tire dust as a filler reinforcement or cheapener in polymer composite foam is one of the solutions to overcome the waste tire disposal issue where it is indirectly improve the damping behavior as well as noise absorption characteristic of produced PU based composite foams