UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF PROCESSING PARAMETERS TO MAXIMIZE THE PHYSICAL AND MECHANICAL PROPERTIES OF NATURAL RUBBER COMPOSITES FOR ENGINE MOUNT

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

by

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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Sekian dimaklumkan. Terima kasih.

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I hereby, declared this report entitled "Optimization of Processing Parameters to Maximize the Physical and Mechanical Properties of Natural Rubber Composites for Engine Mount" is the results of my own research except as cited in references.

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Date : 26th June 2019

APPROVAL

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

……………………………………………

(**Profesor Madya Dr. Noraiham binti Mohamad)**

ABSTRAK

Komposit getah asli (NR) mempunyai banyak manfaat dan salah satu aplikasi utamanya ialah pengeluaran getah pemegang enjin. Laporan ini menumpukan kepada pengoptimuman parameter pemprosesan menggunakan Metodologi Permukaan Sambutan (RSM). Ujian dan analisis telah dilakukan terhadap sebatian komposit NR dibekalkan oleh HML Auto Industries Sdn Bhd. Pencirian sebatian komposit NR dilakukan menggunakan Spektroskopi Inframerah Transformasi Fourier (FTIR), Densimeter Elektronik dan Pengimbasan Perbezaan Kalorimeter (DSC). Kemudian, faktoran aras dua reka bentuk eksperimen digunakan untuk merancang eksperimen tiga parameter proses penekan haba panas dari HML Auto Industries Sdn Bhd; suhu (140-180°C), masa permatangan (5-15 minit) dan tekanan (100-140kg/cm^2). 11 sampel telah diperolehi dan diuji. Seterusnya, ujian mekanikal dan fizikal telah dijalankan untuk menentukan tegangan, kekerasan, ciri pembengkakan dan ketumpatan. Keputusan menunjukkan sampel 7 (suhu: 140°C, masa permatangan: 15 minit dan tekanan: 140kg/cm^2) adalah yang terbaik dengan nilai tegangan 21.73MPa, ketumpatan 1.21g/cm^3, pemanjangan pada waktu rehat 372.59%, modulus 100% 5.09MPa, modulus 300% 17.07MPa, kekerasan 15.43 dan pengambilan toluene 107.69%. Manakala sampel 2 (S2) dan 8 (S8) adalah yang paling teruk. S2 (suhu: 180°C, masa permatangan: 5 minit dan tekanan: 100kg/cm^2) kurang matang dengan nilai tegangan 17.25MPa, ketumpatan 1.12g/cm^3, pemanjangan pada waktu rehat 388.50%, modulus 100% 3.35MPa, modulus 300% 12.51MPa, kekerasan 12.83 dan pengambilan toluene 145.45%. S8 (suhu: 180°C, masa permatangan: 15 minit dan tekanan: 140kg/cm^2) pula terlebih matang dengan nilai tegangan 18.49MPa, ketumpatan 1.11g/cm^3, pemanjangan pada waktu rehat 371.19%, modulus 100% 3.53MPa, modulus 300% 13.47MPa, kekerasan 8.86 and pengambilan toluene 133.33%. Data turut disokong dengan analisis Microskop Imbasan Elektron (SEM), FTIR, pembelauan sinar-X (XRD) dan DSC. Keseluruhannya, pengoptimuman parameter pemprosesan berupaya memaksimumkan sifat mekanikal dan fizikal untuk getah pemegang enjin.

ABSTRACT

Natural rubber (NR) composites have abundant benefits and one of its main application is the production of engine mounting. This research focuses on the optimization of processing parameters using Response Surface Methodology (RSM). Testing and analysis have been carried out on NR composites compound provided by company HML Auto Industries Sdn Bhd. The characterization of NR composites compound was done using Fourier Transform Infrared Spectroscopy (FTIR), Electronic Densimeter and Differential Scanning Calorimeter (DSC). Then, design of experiment two-level full factorial is used to plan for the experiments of three process parameters utilizing of hot press obtained from HML Auto Industries Sdn Bhd; temperature (140-180°C), curing time (5-15 minutes) and pressure (100-140kg/cm^2). A set of 11 samples was obtained and further tested. Next, physical and mechanical testing were conducted for determination of tensile strength, hardness, swelling characteristics and density. Result shows that sample 7 (S7) (temperature: 140°C, curing time: 15 minutes and pressure: 140kg/cm^2) was the best with tensile strength of 21.73MPa, density of 1.21g/cm^3, elongation at break of 372.59%, modulus 100% of 5.09MPa, modulus 300% of 17.07MPa, hardness of 15.43 and toluene uptake of 107.69%. While the worst samples were sample 2 (S2) and 8 (S8). S2 (temperature: 180°C, curing time: 5 minutes and pressure: 100kg/cm^2) was the worst as it was uncured with tensile strength of 17.25MPa, density of 1.12g/cm^3, elongation at break of 388.50%, modulus 100% of 3.35MPa, modulus 300% of 12.51MPa, hardness of 12.83 and toluene uptake of 145.45%. S8 (temperature: 180°C, curing time: 15 minutes and pressure: 140kg/cm^2) was the worst too as it was over cured with tensile strength of 18.49MPa, density of 1.11g/cm^3, elongation at break of 371.19%, modulus 100% of 3.53MPa, modulus 300% of 13.47MPa, hardness of 8.86 and toluene uptake of 133.33%. Data analysis was further supported with Scanning Electron Microscopy (SEM), FTIR, X-ray diffraction (XRD) and DSC each. Overall, the optimization of processing parameters capable on maximizing the physical and mechanical properties of rubber especially for engine mount.

DEDICATION

To my beloved mother, Noorfizam binti Omar
my appreciated father, Abd Ghani bin Shaari
my adored sister, Intan Hanani binti Abd Ghani
and my kind-hearted best friend, Ammar Fakhrullah bin Arifin
for giving words of inspiration and encouragement me in the pursuit of excellence, moral support, money, cooperation, and also understandings.
Thanks for all you did. This work is dedicated to them.

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LIST OF ABBREVIATIONS

ASTM	-	American Standard Testing Machine
BR	-	Butadiene Rubber
CB	-	Carbon Black
DOE	-	Design of Expert
DSC	-	Differential Scanning Calorimetry
ENR	-	Epoxidized Natural Rubber
ENRAN	-	Epoxidized Natural Rubber-Alumina
ER	-	Electrorheological
FTIR	-	Fourier Transform Infrared Spectroscopy
MR	-	Magnetorheological
N&V	-	Noise and Vibration
NBR	-	Nitrile Rubber
NR	-	Natural Rubber
PU	-	Polyurethane
PZT	-	Piezoelectric
RSM	-	Response Surface Methodology
SBR	-	Styrene and Butadiene Rubber
SEM	-	Scanning Electron Microscopy
SR	-	Synthetic Rubber
XRD	-	X-ray Diffraction

LIST OF SYMBOLS

%	-	Percent
°C	-	Degree Celsius
°C/min	-	Degree per Minute
Hz	-	Hertz
mg	-	Milligram
Mins	-	Minutes
mm	-	Millimetre
mm/min	-	Millimetre per Minute
MPa	-	Mega Pascal
T_g	-	Glass Transition Temperature
T_m	-	Melting Temperature
Kg/cm^2	-	Kilogram per Centimetre Square

CHAPTER 1

INTRODUCTION

This chapter covers the background of study, problem statement, objectives, scope, significant of study, organization of report and summary.

1.1 Background of Study

In recent time, engine mounts have been used to isolate the vibration from engine and car body. Based on the research, the engine mounts typically are made from combination of rubber and metal to avoid it hit against the chassis and engine. The rubber part might also fill with liquid or oil to reduce the vibrations and noise. Engine mounts performance and life span usually affected by the temperature, heat and vibration that acting on the engine mounts. High performance of engine mounts increases as per time increases. This is because the demand of new and modern vehicles is increase which a lot of them offering high efficiency, economical and comfort. According to Richard (1980), Inland was the first involved in engine mounting in 1920s and the production was released in 1927. The engine mounts are coming from the moulded rubber steering wheel product line. It has been used since the early stage of internal combustion engine (Azammi *et al.*, 2018).

Elastomeric mounts are the first generation of engine mounts (Yadollah and Abdolreza, 2011). It has been used in automotive since 1930s (Alkhatib, 2013). Walter Chrysler was the first person who encouraged the adoption of rubber vibration-isolating mounts. He innovated the features car using six-cylinder engine which was supported by three points of rubber mounts and rested on it. In 1940s, engine mounts are already applied to the aircraft (Peng *et al.*, 2015).

In current usage, the evolution for engine mounts gives the good result at the end of the day. Since the vehicle becomes lighter, therefore the engine mounts also need to be lighter. This is called an evolution of components. Usually, they used natural rubber (NR) as a polymer that is joined together with metal and it gives the simple terms which is a rubber-to-metal component. This NR compound is bonded to metal parts during vulcanised process. When it is vulcanised, it will form an elastomer which is elastic and dimensionally stable. The elastomer can deform under stress but return to its original shape when the stress is relieved.

According to Mike (2018), the quality parameters which is the most important part for the engine mount to function well is being ignored by the manufacturer. This can give bad effects to the car and can damage the engine and gear box components. Some of the existing engine mounts in the market also have unsuitable characteristic for the rubber part which is it simply glued together with the metal part rather than chemically bonded during vulcanisation. Usually, they do not do the fatigue tests at operating temperature and thus gives the effect on rubber fatigue properties. Most of the engine mounts will last long until five to seven years only (David, 2018). The research state that the problems will slowly be showed when the rubber part breaks or when the liquid inside it starts to leak.

Optimization is crucial in engineering and there is a big gap between the existing researches. There are huge a range of processes available in industries however, the literature optimization of processing parameters specific for engine mount is search. This optimization will help to increase the mechanical and physical properties of natural rubber composites for engine mounts in future. For this motivation, a series of experiments and analyses have been carried out to see the effect of processing parameters to the NR composites. The data analyses are interpreted using response surface methodology (RSM) and this will help to gives the best result for NR composite that is used in engine mounts. The NR composites is supplied by HML Auto Industries Sdn Bhd and thus the study is started with fabricate the compound given using parameters in RSM.

1.2 Problem Statement

Even though now is in 21st century, there are still numbers of original equipment manufacturer as well as car sale manufacturer of the automotive components utilizes the elastomeric (passive) engine mounts. They have used elastomeric mounts to reduce the noise and vibration (N&V) level from chassis and engine. This elastomeric engine mount is easier to manufacture compared to passive and active engine mounts. Elastomeric engine mount is simple yet affordable engine mount with good function and can be fully optimized. The engine mount needs to withstand the vibration produce by the engine and the road condition that makes the chassis vibrate too.

The current system in HML Auto Industries Sdn Bhd does not has a specific processing parameter to maximize the mechanical and physical properties of NR compound. To select the optimum processing parameters are quite hard and it is become a tough problem (Gordeev *et al.*, 2011). Therefore, there are a lot of lack of studies from previous researchers and there is an urgency to study in this topic. By doing this research, the improvement of performance to the engine mounts can be achieved. Hence, gives the company a new energy saving and high profit system. All the temperature, curing time and pressure to be compress will be considered and thus gives a good recipe for the rubber engine mounts. This recipe will also help to meet the requirements such as high fatigue strength, temperature resistance, ageing resistance and recyclability.

Even though there is a range of processes, there is also limited studies to be referred. This optimization will help to increase the mechanical and physical properties of NR composites for engine mounts in future. From this motivation, a series of experiments and analyses have been carried out to see the effect of processing parameters to the NR composites. The data analyzed are interpreted using RSM and this will help to gives the best result for NR composites used in engine mounts. The study is started with fabricate the compound given using parameters in RSM and this will help to gives the best result for NR composite that used in engine mounts. The NR composites was supplied by HML Auto Industries Sdn Bhd and thus the study is started with fabricate the compound given using parameters in RSM.

RSM has been chosen to be used in this study because it is the most suitable techniques compared to Taguchi and others. RSM can includes the experimental designs, model fitting and diagnosing techniques (Sriadhar *et al.*, 2001). Based on the research, RSM is good used in optimizing the rubber compounding compared to others because it can precisely measure and controlled.

1.3 Objective

The objectives of this study are as follows:

1. To optimize the hot press processing parameters (temperature, curing time, pressure) for maximizing the physical and mechanical properties of NR composites using RSM
2. To characterize the thermal, structural and morphological characteristic of the NR composites for the effect of processing parameters

1.4 Scope

The study is mainly focusing on the optimization of processing parameters for NR composites that is used in engine mounts. This optimization is to maximize the mechanical and physical properties of the NR composites. The NR compound is provided by the HML Auto Industries Sdn Bhd. The parameters given by the company to be used were (1) temperature: 140-180 ˚C, (2) pressure: 100-140 kg/cm^2 and (3) curing time: 5-15 minutes. All the parameters were put in RSM using Design of Expert (DOE) Version 6.0.8. After that, the NR was fabricated using hot press machine. The vulcanized NR is tested for its mechanical and physical properties which are tensile strength, elongation at break, modulus 100%, modulus 300%, hardness, swelling measurement and density. Then, numerical optimization was tested using DOE again after the result of mechanical and physical properties was ready. Finally, the data is analyzed, supported characterized by morphological and thermal characteristic.

1.5 Significant of Study

There are some potential benefits that can be gained by the company after the completion of this study. The optimization of the processing parameters will give the company more profit and produce a good quality of engine mounts in the future. The efficiency of the elastomeric engine mounts will be maximized, and this can help to give a longer life to the engine mounts too. The company will have a specific processing parameter that is used to the NR compound that they get from the supplier and this will make sure that the NR compound has the highest mechanical and physical properties.

1.6 Organization of Report

This report is divided into five chapters that describe the analytical and experimental research performed.

Chapter 1: This chapter is an introduction to the study that presents the background of study, problem statement, objectives, scope, significant of study, organization of report and summary of chapter 1.

Chapter 2: In chapter 2, a detailed literature review of relevant theory related to engine mounts are discussed. Previous investigations on the issues and current studies of elastomeric engine mounts are proposed as well. The important elements include the optimization of processing parameters and related experimental testing.

Chapter 3: This chapter details the methodology used for overall research work, raw materials, materials characterization, samples preparation and procedure property analysis and testing.

Chapter 4: In this chapter, a discussion of observation, results, analysis and evaluation done through the study.

Chapter 5: Recommendation or suggestion for future works and improvement of this research were discussed here in this chapter.

1.7 Summary

This chapter is explained about the introduction to this topic. There is some history of engine mounts, the materials that usually used in engine mounts and the problems that the existing engine mounts have. Elastomeric engine mount has been chosen because semi-active and active engine mounts need higher cost and maintenance. Not all vehicle is suitable to use the advance technology yet. The main objectives of this study is to have an optimum processing parameters to increase the mechanical and physical properties of NR composites. These parameters are important to have so that the company can produce high quality of engine mounts and can build trust of their clients. The experimental is done in the lab using NR samples from the company. The data is analyzed using RSM and the result has been observed and recorded. Finally, all the results will be shown to the company so that they will understand more and accept this research.

CHAPTER 2

LITERATURE REVIEW

This chapter generally describes about the types, materials, processing and properties of the engine mount and rubber composite. Major factors controlling the performance of rubber composites were briefly described. Special emphasis was given on the methods using RSM as it plays an important role on optimization of natural rubber composites. This chapter also includes the related study by previous researchers on the engine mount, rubber composites and the method use for optimization.

2.1 Engine Mount

In typical car, there is the part that holds the engine of the car and it is called engine mount (Samarins, 2017). From the research, it stated that there are 3 or 4 mounts that usually bolted together with the engine of the car and it consist of 2 parts which 1 part of it is bolted to the chassis and the other one is holding the engine. Yadavalli and Manjunatha (2013) claimed that to reduce the transmission of the engine vibration to the car body, an engine mount system is needed. The researchers also said that this engine mounting system is usually made of rubber and metal.

Ashrafiuon and Nataraj (1985) said that usually the reduction of noise and vibration (N&V) is achieved by using rubber mounts that connected to base structure. Usually rubber is moulded as a spring with the stiffness coefficient which correspond to the damping value. The engine mounts also should be flexible to the response of the engine. Figure 2.1 shows the engine mount system in the engine car.