UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SURFACE CHARACTERIZATION OF WASTE TYRE DERIVED CRUMB RUBBER

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BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY WITH HONOURS

2022

Faculty of Mechanical and Manufacturing Engineering Technology

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A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Manufacturing Engineering Technology with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

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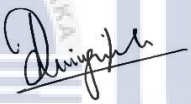
Signature : 

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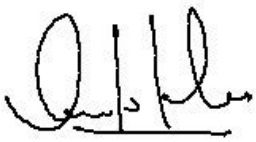
Signature : 

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DEDICATION

Dedicated to

My beloved Parents, Sockalingam RK Suppiah and KamalaDevi Chelladury

My sister, Vickneswaary Sockalingam

My Supervisor, Dr. Lau Kok Tee for his constant support, understanding and encouragement.

ABSTRACT

Nowadays, automobiles industries has become one of the most important industry in the world. The production and consumption of tyres are happening at a larger rate around the world. This contributes to a lot of scrap tyres which does not decomposed easily and pollutes the environment. This research addresses the problem by utilizing valuable scraps and explores the possibility of reducing natural rubber and substituting them with waste tyre derived crumb rubber (WTCR)/Standard Malaysian Rubber (SMR) blends for new application. The aims of this study are to characterize the surface properties of the WTCR by using FTIR and to determine the effect of particle size of WTCR on the surface property. The Fourier Transform Infrared Spectroscopy (FTIR), Thermo-gravimetric Analysis (TGA) and Scanning Electron Microscopy (SEM) of WTCR were used to support the study. The WTCR were prepared with different particle size (400 μm, 40 μm and 75 μm) using sieving analysis. The obtained results from FTIR, TGA and SEM were studied to understand the interaction of WTCR with Standard Malaysian Rubber (SMR). The surface properties of the WTCR were affected by particle size of the samples. The study discovered the finer crumb rubber particles have better adhesion with the SMR.

ABSTRAK

Pada masa kini, industri automobil telah menjadi salah satu industri terpenting di dunia. Pengeluaran dan penggunaan tayar berlaku pada kadar yang lebih besar di seluruh dunia. Ini menyumbang kepada banyak tayar sekerap yang tidak mudah reput dan mencemarkan alam sekitar. Penyelidikan ini menangani masalah dengan menggunakan sisa berharga dan meneroka kemungkinan mengurangkan getah asli dan menggantikannya dengan campuran getah serpihan terbitan tayar buangan (WTCR)/Getah Standard Malaysia (SMR) untuk penggunaan baharu. Matlamat kajian ini adalah untuk mencirikan sifat permukaan WTCR dengan menggunakan FTIR dan untuk menentukan kesan saiz zarah WTCR ke atas sifat permukaan. Spektroskopi Inframerah Transformasi Fourier (FTIR), Analisis Termo-gravimetrik (TGA) dan Mikroskopi Elektron Pengimbasan (SEM) WTCR digunakan untuk menyokong kajian. WTCR telah disediakan dengan saiz zarah yang berbeza (400 µm, 40 µm dan 75 µm) menggunakan analisis penapisan. Keputusan yang diperolehi dari FTIR, TGA dan SEM telah dikaji untuk memahami interaksi WTCR dengan Getah Standard Malaysia (SMR). Sifat permukaan WTCR dipengaruhi oleh saiz zarah sampel. Kajian mendapati zarah getah serbuk yang lebih halus mempunyai lekatan yang lebih baik dengan SMR.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to the almighty god for all the blessings and for guiding me throughout the completion of this thesis. I am also very grateful to Universiti Teknikal Malaysia Malacca (UTeM) for providing the opportunity to carry out my final year research.

This project will not be possible without the immense help and support from my main supervisor, Dr. Lau Kok Tee, Universiti Teknikal Malaysia Malacca (UTeM) and industry co-supervisor, Nurzallia Mohd Saad, Sunrich Integrated Sdn Bhd. They have taken a great interest in the project as well as my personal development as a student. I can only be forever grateful for all the motivation, guidance and constructive criticism received.

Finally, I would like to sincerely thank my beloved sister, Vickneswaary Sockalingam, for her help and support to complete this thesis. I would also like to thank my beloved parents for everything that they have done for me.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
PSI	-	Pound per square inch
Wt%	-	Weight Percentage
Kg	-	Kilogram
Phr	-	Part per hundred rubber
nm	-	Nano meter
°C	-	Degree Celcius
MS	-	Mechanical Separation
°	-	Degree
SMR	-	Standard Malaysian Rubber
WTCR	-	Waste Tyre Derived Crumb Rubber
SEM	-	Scanning Electron Microscopy
ASTM	-	American Society for Testing and Material
ISO	-	International Organization for Standardization
JIS	-	Japanese Industrial Standard
IRHD	-	International Rubber Hardness Degrees

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CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, transportation has become one of the most important industries in the world. Tyre industries plays a bigger role in automobiles and transportation services which contributes wider part of the country's economy (Dick, 2001). Natural rubber has become the choice for most automobile industries is because it has a better abrasion and an excellent flexibility. Natural rubber has a good heat resistance while the physical properties of a rubbers will remains constant as the temperature differs. Hence, most countries utilized natural rubbers more compared to synthetic. The resistance to flame of the natural rubber also makes it a good insulator for electrical devices. As natural rubbers are dominating in the industries, waste tire derived crumb rubber have a good possibilities of occupying a certain part of the rubber economy.

Over the years, tyres manufacturing industries develops their technologies and standards to compete among the each other manufacturers. As a result, there are large stockpiles of used tyres. Automobile and tyre industries has been constantly researching on the method to decrease the scarp of used tyres in different applications. Waste tyres are not environmental friendly and will not decomposed easily. According to the U.S. Tire Manufacturers Association, 300 million of waste tyres are produced every year and Algeria estimates their scrapped tyres are approximately 25,918 tons annually. A new generation of ideas and innovative methods to recycle the millions of tyres scraps were implemented in

various countries in sectors such as farming, transportation, construction, and interior design. Tyre and automobile industry generates new techniques to reuse the waste old tyres and generates profits from it. One of the promising ideas is to utilize the old tyres by rethreading it. Tyre rethreading is a method and process renewing and reusing an old tyre. This is a method of removing the worn casing of an old tyre and replacing it with a renewed thread and sidewall rubber that will go through a mechanical and chemical processed to produce a newly made thread pattern to the old tyre.

1.2 Problem Statement

Waste tyre derived crumb rubber can be reused as a replacement for natural rubber that contributes better environment avoiding pollutions (Fazli and Rodrigue, 2020). The usage of existing resources can also be decrease as the crumb rubber reduces the use of natural rubbers in the markets. Besides, the market price for crumb rubber is lower comparable to the natural rubbers giving both the manufacturer and consumer an advantage in terms of price. Hence, manufacturers should consider to utilize valuable scraps such as waste tyre derived crumb rubber to reduce pollution, lower production and maintenance costs and eventually to develop the economy and environment.

Waste tyres requires wider space to store it and it needs to be disposed in a safest way. Dumping used tyres along the side of the road is illegal and it will cause a lot of trouble to the environment in terms of hygiene and health. Open dumping the tyres would accumulates water and eventually breeds insects such as Aedes mosquito, mice, virus and many mores which will be harmful to the neighbourhood. Burning the tyres would cause a terrible effect to the environment as it would release harmful and toxic gases that might cause a severe air pollution. Burying the tyres would also not recommended since requires wider land. It is also unlikely to decompose and would eventually emerge from the buried place.

Throughout years, manufacturers were constantly studying the process and ways to reuse the old tyres to make use of the economic benefits. Recycling and reuse of old worn tyres raises benefits for the environment. Besides, the waste tyre derived crumb rubber can be used as an alternative material for natural rubber to produce new applications in manufacturing industries. The utilization of waste tyre derived crumb rubber would reduce the usage of natural rubber and at the same time reduces the pollutions.

Moreover, it is important to study the surface properties of the crumb rubber to understand the quality of interaction of crumb rubber and Standard Malaysian Rubber (SMR). This is because the surface property of crumb rubber determines the quality of possible new application that can be fabricated using the crumb rubber and SMR bind such as door stopper, insulator on electrical appliances, baby proofs, handles and many mores. More experimental work of waste tyre derived crumb rubber is needed to welcome wider manufacturers to utilize the crumb rubber and helps save the environment. Hence, this study of surface property is important to understand the effect of waste tyre derived crumb rubber (WTCR) additions on mechanical properties of SMR/WTCR blends.

1.3 Research Objective

The objectives of the research as follows:

a) To characterize the surface properties of the waste tyre derived crumb rubber (WTCR) by Fourier Transform Infrared (FTIR).

b) To determine the effect of crumb rubber particle size on the surface property.

1.4 Scope

The scope of this study is revolves around the surface property of crumb rubber particles. The rubber chips is the mechanically processed waste tyre derived crumb rubber. The surface property of crumb rubber is important to understand the adhesion of waste tyre derived crumb rubber and SMR blends. The surface properties of crumb rubber includes thermal, microstructure and particle size analysis. The crumb rubber which is raw material used in this study which will be characterized using Fourier-transform infrared spectroscopy (FTIR). The FTIR analysis is important to study the surface property of the crumb rubber.

Besides, this study for the surface property of crumb rubber is also revolves around the FTIR spectrum of the crumb rubber particles of different sizes. The particle size measurement will be done through the mechanical sieving process. Three different size of crumb rubber sample will be obtained and the different particle sizes of crumb rubber will be compared for their FTIR results. This findings is important to study the effect of the crumb rubber particle size on the surface property.

Moreover, the findings will be supported by Thermo-gravimetric and Scanning Electron Microscopy analysis. The SEM analysis used to study the microstructure of the crumb rubber whereas the TGA is to study the thermal properties. As manufacturers utilize the crumb rubber more, the natural source can be sustained for longer years. The surface properties of crumb rubber must be known in order to optimise the quality of interaction of the crumb rubber with SMR or other polymer matrix. Altogether, the scope of this study revolves around the surface properties of waste tyre derived crumb rubber.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter mainly focused on the literature and scholarly paper that discuss about the raw material, preparation and the characterization in this study. A chapter fully dedicated for literature review is important to understand the foundation of this study. Besides, the open questions left for the future researchers from the previous study can also be identified and answered with a better clarity. On the other hand, this chapter also discusses the method or techniques used in rubber processing technology such as rubber compounding, mixing, shaping, vulcanization and many mores. The properties generated from the addition amount of waste tyre derived crumb rubber are tensile stress-strain, hardness, modulus of elasticity, cure characteristics and Scanning Electron Microscopic (SEM) images. These processes that studied by previous researchers were discussed in this chapter.

2.2 Raw Material

Raw materials are the basic material and the primary substance needed to fabricate a product, mixture, to produce goods and many mores. Raw material is needed to sustain any production process. The primary raw material used in rubber processing technology is mechanically reclaimed waste rubber. Besides, the secondary raw material used to bind the reclaimed waste rubber is the Standard Malaysian Rubber (SMR). Raw materials such as sulfur and carbon black are added into the rubber compounding process to improve the performances of the rubber compound.

2.2.1 Standard Malaysian Rubber (SMR)

Over the years, our country has been producing larger amount of rubber setting up a benchmark in the international market (Lembaga Getah Malaysia, 2010). The rate of our productions are widely impressive since we are the world's fifth largest natural rubber maker in comparison with other countries. The Standard Malaysian Rubber (SMR) has grown to become the tools of opportunities and profitable growth in the automotive industries. These vast growth increases the countries' economy and reformed the face of the Malaysian economy causing higher demands among automotive sectors for the Standard Malaysian Rubber (SMR). Currently the fifth largest natural rubber producer in the world, Malaysia aims to expand rubber plantation areas by 2020 and increase its output of natural rubber, through the Rubber Production Incentive Scheme and infrastructure improvement to boost latex collection. The size of the tanned area is targeted to expand from 670,000 hectares to 1,000,000 hectares. Malaysian Rubber Board research and development efforts expect to increase productivity rates from 1.2 ton per hectare to 2 ton per hectare. Its local rubber glove manufactures are also encouraged to use local latex to reduce latex imports. Consumers can look to Malaysia as a source of quality raw rubber of SMR (Standard Malaysian Rubber) grades.

The production of SMR are made from a raw rubber material selected from particular rubber plantation. The selection process of raw rubber material need strict and focused process to ensure the specification requirements of the Standard Malaysian Rubber are fulfilled. As one of the world largest rubber producer, the consistency in the quality of the rubber are needed throughout to sustain in the international market. Hence, rubber manufacturers and processors has been taking continuous efforts to improve the quality of the SMR to sustain the demand of the product in the international market. Besides, the raise

of demand for the virgin rubber and followed by the larger usage of the natural resources such as rubber requires immediate strategies at all aspects to sustain and control the usage of the natural rubber. This includes adoption of new technologies to strengthen SMR and development of new types of rubbers as alternatives to SMR through cooperation between Malaysian Rubber Board (LGM) and the industry.

2.2.2 Carbon Black

Most rubber compounds contains 30% of carbon black which affects the characteristics, performances and quality of the end product in a rubber factory (Gasc et al., 2018). Carbon black is highly valuable that it certainly increase the quality of a rubber product regardless of whether it is a tyre segment or an industrial tyre product. Carbon black has a reinforcement character that acts as a colloidal form affecting the size, shape and surface chemistry of the sample. The ability of a carbon black to reinforce the rubber are based on the factors involved such as the surface area, structure and the surface activity. Carbon black owes its reinforcing character depends on the surface available to bind with the elastomer. The particle size of a carbon black is in the range between 10 to 250 nm in diameter. The Figure 2.1 shows the addition of a carbon black on an unreinforced rubber that makes the molecules strong by creating friction causing the rubber to not rupture easily.

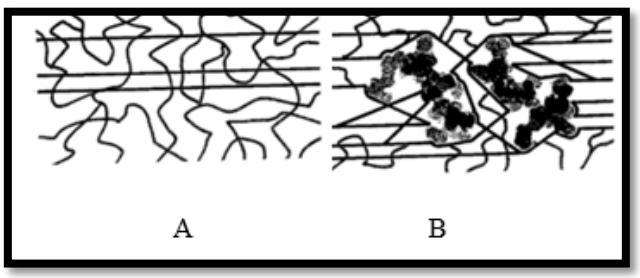

Figure 2.1 Unreinforced Rubber (A), Addition of Carbon Black on Unreinforced Rubber (B), (Dick, 2001)

Carbon black is added following the polymer in conventional mixing under different stages of mixing process (Dick, 2001). The viscosity of the mix depends on the amount of the carbon black. The common additive added in the final process of mixing are sulfur and curatives. The quality, texture and performances of the composition are depends on the quality of the carbon black. The dispersion level also depends on the right choice of carbon black. The reinforced rubber appears in black colour due to the addition of the carbon black at a level up to 4 wt% and above. In certain rubber production, the addition of the carbon black is at higher levels to reinforce the elastomer depends on the specification of the end product. The mechanical properties of the elastomer such as the tensile stress, elongation, hardness and yield strength will improved after the addition of the carbon black on the elastomer forming stronger physical and chemical bonds. On top of that, the automotive related parts such as the door, window seals, radiator hoses, steering boots and many mores requires improvement in terms of smoothness, colours, and gloss at a cheaper costs. The outcome requirement of the compound is affected by carbon black.

2.2.3 Processing Oil

Processing oil is also widely added into many polymers to lower the viscosity (Dick, 2001). The addition of the oil are before the drying process of the polymer so that it will absorb into the polymer completely. It is important for the analyst to choose the right solvent to avoid the polymer from dissolving into the oil. The extender oils will be added to the polymer at the levels of 37.5 phr and above while process oils are added to the rubber compound as a process aids at 5 to 20 phr during the manufacturing process. To decrease the viscosity and to increase the failure properties such as the stress or strain and the hardness of the end product. In the mixing process, the oil's wetting and lubricity properties will be transmit subsequently at all process such as calendaring, sheeting, extruding, transfer

molding and mold flow. The usage of process oils are practiced by most of the compound maker to reduce to the cost and to cut down the usage of polymer and carbon black. In addition, adding process oil at a higher rate would lower the hardness and modulus of elasticity while increasing the elongation, and decrease the abrasion resistance. However, this will cause a mold fouling or a buildup during the injection molding process. Process oils affects the compound properties in terms of viscosity, hardness, modulus and elongation. It is inversely proportional to the viscosity. The higher the processing oils are added, the lower the viscosity will be whereas carbon black reacts oppositely to process oils. The higher carbon black are added, the higher viscosity of the compound will be. Hence, the mixing of the carbon black and oil are simultaneously adjusted to sustain the requirement properties level of the end product. For example, the N134 type is the addition of a 1.3Phr of process oil to maintain the hardness as the carbon black becomes more reinforcing whereas an addition of 0.7Phr of process oil are required as the carbon black becomes less reinforcing.

2.2.4 Sulphur

Sulphur is one of the ingredients used in the rubber compounding process where the sulphur acts as a vulcanizing agent to produce crosslinking between rubber chains (Akrochem, 2021.). The elasticity behaviour of the sulphur occurs at a state of temperature in the range of 40°C to 70°C and increases the surface area of the particles. Then, the melting sulphur is uniformly distributed in the rubber matrix and helps to improve the properties of the rubber. The number of sulphur atoms that existed in a cross link varies according to the type of vulcanization system. The type of cure system used for vulcanization for the fabrication of tyre rethreading is semi efficient vulcanization system. The number of sulphur atoms existed per cross link are 5 to 10 in this type of cure system. The process of vulcanization by sulphur independently is longer and might take several hours even at the