EFFECT OF CRYOGRINDING ON SURFACE PROPERTIES OF WASTE TYRE DERIVED RECLAIMED RUBBER

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DECLARATION

I declare that this thesis entitled " Effect Of Cryogrinding On Surface Properties Of Waste Tyre Derived Reclaimed Rubber. " is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

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DEDICATION

To

My beloved parents and sister

A strong and emotional support, encouragement for me to not to give up in my completion of this study.

My supervisor, Professor Madya Ts. Dr. Lau kok Tee

Who patiently guides me and gives me valuable knowledge.

My teammates and friends

Who giving support and accompanied me in the completion of this study.

ABSTRACT

Rubber is a viscous and elastic elastomer. Natural rubber is an elastomer with excellent elasticity, durability and damping. It's inferior properties can be enhanced by compounding with other polymers or adding additives. However, an increase in waste tyre rubber disposal in landfills has impacted air pollution. In fact, cryogenic grinding is adopted for waste tyre rubber processing. Also, rising demand for natural rubber has led to depletion. Then, waste tyre rubber is introduced as a raw material into natural rubber compound, cutting the final product cost. Prior to grinding, reclaiming technology is employed to process waste tyre rubber. However, reclaimed rubber is non-polar. To clarify, one of the purpose of this study is to investigate the effect of the reclaiming technique to the chemical structure of waste tyre derived reclaimed rubber (WTRR). Following that, pulverization affects the characteristics of reclaimed rubber itself. Hence, the effect of cryogrinding on surface properties of waste tyre derived reclaimed rubber (WTRR) in different particle size was studied. As reported that WTRR has a weak polar hydroxyl bond (O-H) as determined by Fourier Transform Infrared Spectroscopy (FTIR). Moreover, the intensity of WTRR's peak after cryogenic grinding decreased with the increasing of particle size. On the other hand, Scanning Electron Microscope (SEM) analysis showed a smooth surface of WTRR after cryogenic grinding. Thermogravimetric analysis (TGA) indicated that oxygen molecule in O-H bonding affects the thermal stability of WTRR. To sum, cryoground WTRR may not be feasible alternative in rubber compounding. Properties of cryoground WTRR should be improved further.

ABSTRAK

Getah ialah elastomer likat dan elastik. Getah asli ialah elastomer dengan keanjalan, ketahanan dan redaman yang baik. Sifat inferiornya boleh dipertingkatkan dengan menggabungkan dengan polimer lain atau menambah bahan tambahan. Walau bagaimanapun, peningkatan dalam pembuangan getah tayar sisa di tapak pelupusan telah memberi kesan kepada pencemaran udara. Malah, pengisaran kriogenik digunakan untuk pemprosesan getah tayar sisa. Selain itu, peningkatan permintaan untuk getah asli telah menyebabkan kehabisan. Kemudian, getah tayar sisa diperkenalkan sebagai bahan mentah ke dalam sebatian getah asli, mengurangkan kos produk akhir. Sebelum mengisar, teknologi tebus guna digunakan untuk memproses getah tayar sisa. Bagaimanapun, getah tebus guna adalah bukan kutub. Untuk memperjelas, salah satu tujuan kajian ini adalah untuk menyiasat kesan teknik tebus guna terhadap struktur kimia tayar buangan getah tebus guna (WTRR). Berikutan itu, penumbuk menjejaskan ciri-ciri getah tebus guna itu sendiri. Oleh itu, kesan pengisaran krio ke atas sifat permukaan tayar buangan getah tebus guna (WTRR) dalam saiz zarah yang berbeza telah dikaji. Seperti yang dilaporkan bahawa WTRR mempunyai ikatan hidroksil polar lemah (O-H) seperti yang ditentukan oleh Fourier Transform Infrared Spectroscopy (FTIR). Selain itu, keamatan puncak WTRR selepas pengisaran kriogenik menurun dengan peningkatan saiz zarah. Sebaliknya, analisis Scanning Electron Microscope (SEM) menunjukkan permukaan licin WTRR selepas pengisaran kriogenik. Analisis termogravimetrik (TGA) menunjukkan bahawa molekul oksigen dalam ikatan O-H mempengaruhi kestabilan terma WTRR. Kesimpulannya, tanah krio mungkin bukan alternatif yang boleh dilaksanakan dalam pengkompaunan getah. Sifat-sifat cryoground WTRR perlu dipertingkatkan lagi.

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LIST OF SYMBOLS AND ABBREVIATIONS

GTR	-	Ground Tyre Rubber
WTRR	-	Waste Tyre Derived Reclaimed Rubber
WTCR	-	Waste Tyre Crumb Rubber
FTIR	-	Fourier Transform Infrared Spectroscopy
SEM	-	Scanning Electron Microscopic
TGA	-	Thermogravimetric analysis

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CHAPTER 1

INTRODUCTION

1.1 Background

Rubber is a kind of unique material with elasticity and viscosity. Rubber is also referred to as elastomer. Elastomers can be categorized into natural and synthetic elastomers. In the manufacturing process, rubber can be processed into various shapes such as compression molding, extrusion and calendering. It can be compounded to have widely varying properties. In addition, mechanical properties of rubber such as hardness, tensile strength and modulus under set strain are always the primary consideration when designing a rubber formula for specific purpose. Therefore, rubber is widely used in human life. Most common applications are tires, automobile supply industry, constructions, textiles and biomedical applications.

Natural rubber, also known as virgin rubber, mainly has resilience, damping performance and good elasticity. However, it does have some imperfections such as low resistance to organic solvent and low heat resistance. Since then, natural rubber need to be chemically modified so that it can enhance the performance and expand the applications of other rubber materials by blending with other polymers or adding additives. Besides, natural rubber is also vulcanized and used in most applications by forming a three-dimensional network structures, which is said to transmit stress almost constantly among the rubber chains. From that, the requirements of natural rubber are getting higher and more attractive (Mente, Motaung and Hlangothi, 2016). In 2020, the global natural rubber market is valued to be closed to 40 billion US dollars, and it is predicted by analysis that the rubber market value will be almost 68.5 billion US dollars in 2026 (CNBC, 2021).

It is estimated that more than 1.2 billion new tyres are produced every year in the world and disposed of at the end of the tyre life. Especially in Europe and the United States, 245 million and 270 million waste tyres have been discarded in landfills (Mushunje, Otieno and Ballim, 2018). It is reported that among the billions of waste tyres thrown into the environment around the world, about 1000 million waste tyres were produced by the passenger vehicles (Khed, Mohammed and Nuruddin, 2018). The lack of citizen's environmental awareness makes the problems of dealing with waste rubber tyres more serious. Buried in landfills and illegal garbage dumps are among common, cheapest and easiest method of disposing waste rubber tyre. The poor disposal of rubber tyres lead to the release of toxic chemicals, and mosquitoes breed in stranded water of disposed tyre. Thereafter, this issue has become a likely hazard to human health worldwide or even the living being and decrease quality of environment (Waste Rubber, 2019).

With the vulcanization process, the formation of three-dimensional network makes the rubber a kind of non-biodegradable material, which can resist many external factors. On account of the complex 3D crosslinked structure and the presence of a high number of different additives inside a tyre formulation, there are many processing method are being carried out to address the issue disposal of waste tyre (Fazli and Rodrigue, 2020). For example, waste tyre can be finely shredding using grinding process. Grinding process is the most common method to manage waste rubber tyres. It includes ambient grinding, wet grinding and cryogenic grinding (Mohajerani et al., 2020). This technique produces ground tire rubber (GTR) , which can be used as a substitute material in natural rubber compounds partially or producing more environmentally friendly composite materials. Through this, discarded tires should no longer be regarded as a pollutant and useless wastes, but rather brings a positive influence on the properties performance of rubber.

1.2 Problem Statement

Malaysia is a major producer of natural rubber in Southeast Asia. According to reports, the amount of rubber consumed for natural rubber goods increased by 2% annually in 2018. As a result of the increased demand for natural rubber, there may be a scarcity of raw material in the future. Natural rubber is also pricey in terms of cost. Subsequently, most rubber manufacturers are experimenting with using waste tyre rubber as a raw resource to partially replace and blend with natural rubber (Husna and Azura, 2020).

Thereafter, the introduction of waste tyre rubber able to reduce the cost of the final product (Zedler et al., 2020). The utilization of waste tyre rubber in the rubber compound has potentially manufactured products like floor mats, tread of passenger car, light truck. Therefore, this strategy has allowed sustainable industrial application of tyre recycling technologies. One of the tyre recycling technologies was reclaiming technology, also called as devulcanization. According to the study by Kenawy and Khalil (2021), the authors declared that waste tyre rubber is advocated to be devulcanized before being merged with others rubber compound. However, according to a prior study, pure reclaimed rubber is essentially non-polar (Saeed and Khattab, 2021). A polar group is critical in aiding of interfacial adhesion between two polymers (Kenawy and Khalil, 2021). In order to verify this statement, this study would like to investigate the reclaiming technology to the chemical structure of waste tyre derived reclaimed rubber.

Futhermore, the waste tyre rubber could have a good influence on the properties of rubber compound by adopting appropriate waste rubber processing method. As the waste rubber processing method is one of the key factors affecting the properties of rubber compounds, chemical separation method is employed to remove the contaminants such as metal dust and oil in the waste rubber. It is then grinded to reduce the size of waste rubber dust sheet created by chemical separation, commonly also known as pulverization. A rubber compound containing ground tyre rubber with a smaller particle size will have superior mechanical properties than the one with bigger particles (Hrdlička et al., 2021). Therefore, this research would like to study the effect of cryogrinding on surface properties of waste tyre derived reclaimed rubber (WTRR) in different particle size.

1.3 Research Objective

The objectives of this research as follows:

a) To investigate the effect of the reclaiming technology to the chemical structure of waste tyre derived reclaimed rubber (WTRR).

b) To study the effect of cryogrinding on surface properties of waste tyre derived reclaimed rubber (WTRR) in different particle size.

1.4 Scope of Research

In general, the scope of research is to investigate the effect of the reclaiming technology to the chemical structure of waste tyre derived reclaimed rubber (WTRR) and to study the effect of cryogrinding on surface properties of waste tyre derived reclaimed rubber (WTRR) in different particle size. This study's process flow is divided into 5 steps, including raw material preparation, sample preparation and sample characterization.

The raw material used is the pulverized chemical separation (CS)-grade waste rubber, also called waste tyre derived reclaimed rubber (WTRR). The cost price of waste tyre derived reclaimed rubber (WTRR) dust produced by chemical separation method is about RM 3.00/kg.

First of all, WTRR is immersed and cooled in liquid nitrogen approximately -196°C. The embrittled WTRR is further ground by a blender to obtain smaller particles. Then, the pulverized WTRR is mechanically sieved by siever shaker. 6 groups of samples will be prepared for the characterization of the samples. These 6 samples include 1 sample taken from WTRR before cryogrinding and 5 samples taken from different particle size, including 1.0 – 2.0 mm, 2.0 – 3.15mm, 3.15 – 4.0mm, 4.0 – 5.0mm and > 5.0mm.

The types of characterization carried out on the prepared samples are surface properties, morphological properties and thermogravimetric analysis.

The surface properties of WTRR before and after the cryogrinding are studied by Fourier Transform Infrared Spectroscopy (FTIR) in the range of 400 to 4000 cm^{-1}; the morphological characteristics of WTRR are observed by Scanning Electron Microscope (SEM) at an accelerating voltage of 15kv; and its thermal analysis is characterized by Thermogravimetric Analyzer (TGA), with heating rate at 10 cel/min.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In today's world, waste rubber can be a significant raw material added to the rubber compounds. By varying its particle size, resulting in different properties of rubber compound. Therefore, this chapter will provide an overview of the previous research on recycling method of waste rubber from waste rubber tyre, so as to effectively reuse them. In order to understand the properties of waste rubber more clearly, this chapter will also be introducing the pulverization and blending technologies, additives and sample preparation as well. The knowledge on characterization properties of natural rubber as well as blending of waste rubber with natural rubber are reviewed as they are mostly similar to the properties of waste rubber.

2.2 Natural Rubber

Natural rubber (NR) comes from a kind of tree, which is called *Heavea tree*. It is a kind of milk-like liquid extracted from the tree. This milk-like liquid, called latex, is obtain by tapping the inner skin layer of the tree and collecting it in a cup. Natural rubber is the name of polymer 1,4 cis-polyisoprene. Natural rubber has inherent superior properties such as high abrasion temperature, good tensile strength and elastic reistance (Zhao et al., 2019). As a result, it is utilised as one of the components in the production of rubber tyres for passenger cars, trucks and off-road vehicles. The composition of various tyres is listed below (Formela, 2021):