



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



**BACHELOR OF MANUFACTURING ENGINEERING
TECHNOLOGY (PROCESS AND TECHNOLOGY) WITH
HONOURS**

2022



**Faculty of Mechanical and Manufacturing Engineering
Technology**



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WASTE TYRE DERIVED RECLAIMED RUBBER**

Chan Yu Jie

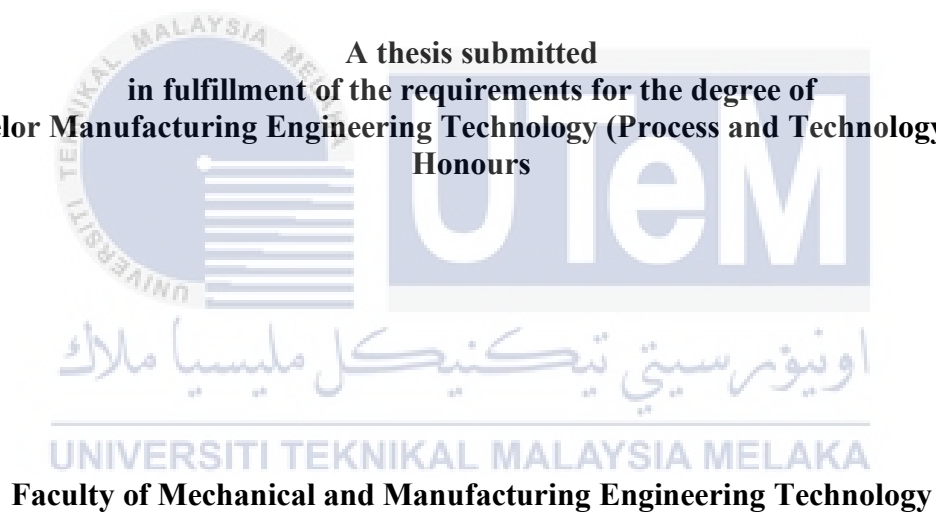
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Honours**

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DERIVED RECLAIMED RUBBER**

CHAN YU JIE

**A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor Manufacturing Engineering Technology (Process and Technology) with
Honours**



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

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.

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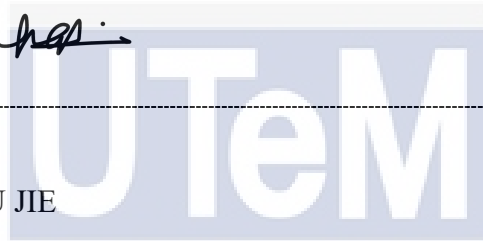
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APPROVAL

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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25 Jan2022

اونيورسيتي تيكنيكل مليسيا ملاك

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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.

اونيورسيتي تيكنيكل مليسيا ملاك

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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.

اونيور سیتی تکنیکل ملیسیا ملاک

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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 memproses 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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TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF SYMBOLS AND ABBREVIATIONS	xi
LIST OF APPENDICES	xii
CHAPTER 1 INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	3
1.3 Research Objective	4
1.4 Scope of Research	4
CHAPTER 2 LITERATURE REVIEW	6
2.1 Introduction	6
2.2 Natural Rubber	6
2.2.1 Chemical Properties of natural rubber	7
2.2.2 Physical Properties of natural rubber	8
2.2.3 Structure of natural rubber	9
2.3 Vulcanization of Natural Rubber	10
2.4 Reclaiming Technology	11
2.5 Pulverization Technology	12
2.6 Sieving	14
2.7 Sample Preparation	16
2.7.1 Rubber Compounding	16
2.7.2 Calendering	17
2.7.3 Compression Molding	17
2.8 Additives	18
2.8.1 Semi-EV as a vulcanization system	18
2.8.2 Carbon Black	20

2.8.3	Processing oil	21
2.9	Characterization properties of natural rubber	22
2.9.1	Characterization of tensile properties of natural rubber with tensile test	22
2.9.2	Characterization of hardness of natural rubber by using Shore A durometer	25
2.9.3	Characterization of cure characteristics of natural rubber by using rheometer	25
2.9.4	Characterization of surface properties of natural rubber using Fourier Transform Infrared Spectroscopy (FTIR)	27
2.9.5	Characterization of morphology of natural rubber using Scanning Electron Microscopic (SEM)	30
2.9.6	Characterization of thermal properties of natural rubber using Thermogravimetric analysis (TGA)	32
2.10	Summary or Research Gap	34
CHAPTER 3 METHODOLOGY		40
3.1	Introduction	40
3.2	Raw materials	42
3.2.1	Waste tyre derived reclaimed rubber (WTRR)	42
3.3	Sample preparation of waste tyre derived reclaimed rubber (WTRR)	43
3.3.1	WTRR size reduction	43
3.3.2	Cryogenic grinding	43
3.3.3	Sieving	45
3.4	Sample Characterization	46
3.4.1	Surface Properties	48
3.4.2	Morphological Properties	48
3.4.3	Thermogravimetric analysis (TGA)	49
CHAPTER 4 RESULTS AND DISCUSSION		50
4.1	Introduction	50
4.2	Fourier Transform Infrared Spectroscopy (FTIR) Analysis	50
4.2.1	Effect of the reclaiming technique to the chemical structure of waste tyre derived reclaimed rubber (WTRR)	50
4.2.2	Effect of cryogrinding on surface properties of waste tyre derived reclaimed rubber (WTRR) in different particle size	53
4.3	Scanning Electron Microscopic (SEM) Analysis	55
4.3.1	Morphological properties	55
4.4	Thermogravimetric Analysis (TGA)	59
4.4.1	Thermal properties	59
4.5	Summary	61
CHAPTER 5 CONCLUSION AND RECOMMENDATIONS		62
5.1	Conclusion	62
5.2	Recommendations	63
5.3	Project Potential	63
REFERENCES		64



LIST OF TABLES

TABLE	TITLE	PAGE
Table 2.1	Composition of passenger, truck and off-road vehicles (Formela, 2021).	7
Table 2.2	Composition of natural rubber latex (Dinsmore, 2007).	7
Table 2.3	The quality standard of different general types of SMR grades natural rubber (Service, n.d.).	8
Table 2.4	Table shows a typical curing system formulation (Nocil, 2017).	19
Table 2.5	Table shows typical Semi-EV curing system formulation for natural rubber (Nocil, 2017).	20
Table 2.6	Summary of reclaiming technology from previous researchers findings	34
Table 2.7	Summary of pulverization technology from previous researchers findings	36
Table 2.8	FTIR peak assignments (Nandiyanto, Oktiani and Ragadhita, 2019) (Merck KGaA, Darmstadt, 2021) (Mohrig, J. R.; Hammond, C. N.; Schatz, 2006).	39
Table 2.9	Examples of infrared spectrum peak position identified in previous study.	39
Table 3.1	General specifications of TYREC M-1 (Jeng Yuan Reclaimed Rubber, 2013).	42
Table 4.1	An overview of the FTIR peaks shown in the figure above.	51
Table 4.2	A summary of FTIR peaks shown in the figure above.	54

LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 2.1	Microstructure of natural rubber (Sisanth et al., 2017).	9
Figure 2.2	Schematic molecular structure of natural rubber (Rowhani and Rainey, 2016).	10
Figure 2.3	Schematic molecular structure of vulcanized natural rubber (Rowhani and Rainey, 2016).	10
Figure 2.4	Diagram (a) and (b) show the different opening size of sieze (Scrap Tire News, n.d.).	15
Figure 2.5	The schematic diagram shows the sieving process (Scrap Tire News, n.d.).	15
Figure 2.6	General structure of a two-roll mill (Ghaleb, Jaafar and Rashid, 2019).	17
Figure 2.7	General configuration of compression molding (Graf, Consulting and Process, 2018).	18
Figure 2.8	Stress-strain curve of natural rubber (Monadjemi, McMahan and Cornish, 2016).	23
Figure 2.9	Figure shows the type of cure curve. (a) is the curve to equilibrium torque, (b) is the cure to a maximum torque with reversion and (c) is the curve to no equilibrium in maximum torque (ASTM D2084, 2016).	27
Figure 2.10	FTIR graph in absorbance mode (Wade Jr, 2006).	28
Figure 2.11	FTIR graph in transmittance mode (Wade Jr, 2006).	28
Figure 2.12	Classification of absorption band (Wade Jr, 2006).	28

Figure 2.13 Example of total reflectance attenuated the spectra of waste tyre rubber and Ground Tyre Rubber (GTR) from water jet pulverization in Fourier Transform Infrared Spectroscopy (FTIR)	29
Figure 2.14 SEM micrograph of cryo-ground GTR (Mangili et al., 2014).	31
Figure 2.15 SEM micrograph of cryo-ground GTR (Araujo-Morera et al., 2021).	31
Figure 2.16 SEM micrographs reclaimed rubber and natural rubber: (a) 30/70 (b) 50/50 (c) 70/30 blend (Zhao et al., 2019).	32
Figure 2.17 TGA thermal curve of ambient ground tyre rubber (Hrdlička et al., 2021).	33
Figure 2.18 TGA thermal curve of cryoground rubber powder (Ayyer, Rosenmayer and Papp, 2012).	33
Figure 3.1 Methodology Flow Chart.	41
Figure 3.2 TYREC M-1 grade waste tyre derived reclaimed rubber (WTRR) (Jeng Yuan Reclaimed Rubber, 2013).	42
Figure 3.3 Processing of cryogenic grinding	44
Figure 3.4 Sieve shaker	45
Figure 3.5 6 samples prepared included before cryo-grinding and after cryo-grinding in 5 different size fractions	47
Figure 3.6 FTIR spectroscopy machine	48
Figure 3.7 Scanning Electron Microscope	49
Figure 3.8 Gold sputtering machine	49
Figure 4.1 Fourier Transform Infrared Spectroscopy (FTIR) of waste tyre rubber (crumb rubber) and devulcanized waste tyre rubber (reclaimed rubber).	
Note: * appeared in the unknown peak.	51

Figure 4.2	Fourier Transform Infrared Spectroscopy (FTIR) of waste tyre derived reclaimed rubber (WTRR) before and after cryogenic grinding.	
	Note: * appeared in the unknown peak	53
Figure 4.3	SEM micrograph of WTRR before cryogrinding.	55
Figure 4.4	SEM micrograph of WTRR with particle size in the range of 1.0 to 2.0mm.	56
Figure 4.5	SEM micrograph of WTRR with particle size in the range 2.0 to 3.15 mm.	56
Figure 4.6	SEM micrograph of WTRR with particle size in the range 3.15 to 4.0 mm.	57
Figure 4.7	SEM micrograph of WTRR with particle size in the range 4.0 to 5.0 mm.	57
Figure 4.8	SEM micrograph of WTRR with particle size in the range > 5.0 mm.	58
Figure 4.9	Thermogravimetric (TGA) graph analysis of WTRR before cryogenic grinding.	60

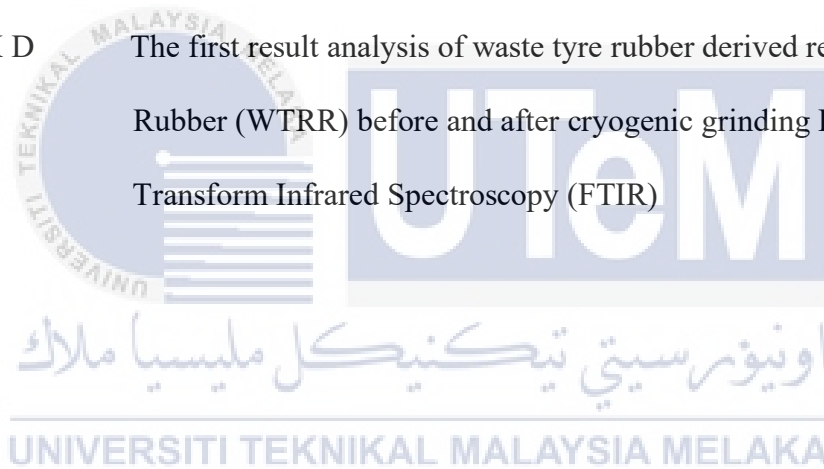
LIST OF SYMBOLS AND ABBREVIATIONS

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



LIST OF APPENDICES

APPENDIX	TITLE	PAGE
APPENDIX A	Gantt Chart for FYP 1	73
APPENDIX B	Gantt Chart for FYP 2	74
APPENDIX C	The first result analysis of waste tyre rubber (crumb rubber) and devulcanized waste tyre rubber (reclaimed rubber) using Fourier Transform Infrared Spectroscopy (FTIR)	75
APPENDIX D	The first result analysis of waste tyre rubber derived reclaimed Rubber (WTRR) before and after cryogenic grinding Fourier Transform Infrared Spectroscopy (FTIR)	76



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.

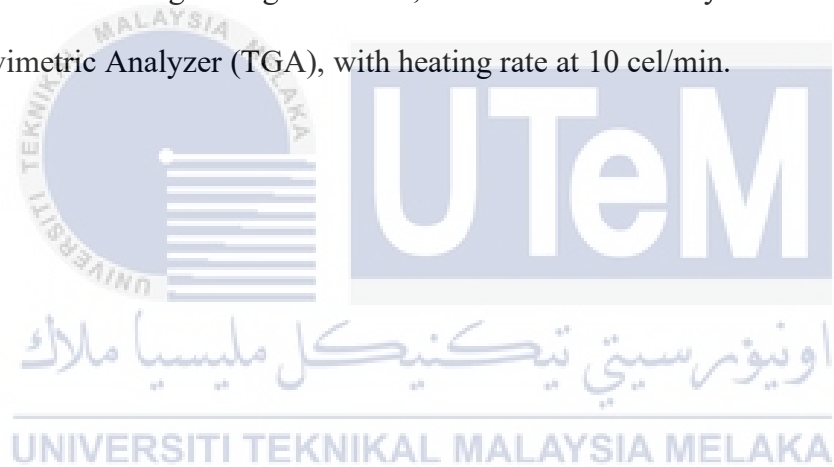
The raw material used is the pulverized chemical separation (CS)-grade waste rubber, also called waste tyre derived reclaimed rubber (WTRR). The cost price of waste tyre derived reclaimed rubber (WTRR) dust produced by chemical separation method is about RM 3.00/kg.

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):