UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHARACTERIZATION AND MECHANICAL PROPERTIES OF TIN DIOXIDE REINFORCED NATURAL RUBBER FOR ELECTRICAL INSULATORS

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DECLARATION

I declare that this report entitled "Characterization and Mechanical Properties of Tin Dioxide Reinforced Natural Rubber For Electrical Insulator" is the result of my study except as cited in the references. The report has not been accepted for any degree and is not currently submitted in the candidature of any other degree.

Signature : Hariez

Name : Muhamad Hariez Bin Shaari

Date : 20 JANUARI 2023

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 Mechanical Engineering Technology (Automotive Technology) with Honours.

Signature : Hairul

Supervisor Name : Mr. Hairul Effendy bin Ab. Maulod

Date : 20 JANUARI 2023

DEDICATION

This report is dedicated to Mr Hairul Effendy bin Ab. Maulod, because none of this would have transpired without his early inspiration, guidance, and excitement. This tribute is especially for my parents. To my father, Shaari Bin Setapa, and mother, Mariah Binti Omar, for their unending love and support, and for teaching me to trust in Allah and value the hard effort. I also dedicate my report to my family, whose unconditional love motivates me to reach a greater goal in finishing this final year project. This devotion is also dedicated to my loving friends who have given me a powerful love shield and have always surrounded me, never allowing any grief to enter my heart.

Thank you.

ABSTRACT

The main objective of this study is on the mechanical and physical properties of Natural Rubber (NR) reinforced Tin Dioxide (SnO_2). Tin Dioxide (SnO_2) is an inorganic-based filler that is used when the melt compounding process is utilised for Natural Rubber. Tin Dioxide was selected for use as a strengthening agent for the mechanical and physical properties of Natural Rubber due to the properties it has that enable it to do so. The primary purpose of this is to determine the composition of Tin Dioxide that is most effective when combined with Natural Rubber. A few tests, including both physical and mechanical ones, will be performed on the compound to identify its properties. In order to investigate the material's different mechanical characteristics, tensile testing will be carried out. The mechanical characteristics of the compound will be determined using a tensile test as well as a Shore hardness test. Under Scanning Electron Microscope, the structure of the compound will be analysed for its morphology. The combination of Natural Rubber compound and Tin Dioxide based on 100 phr of the Natural Rubber and different proportions of tin dioxide (SnO_2) at 0 phr, 0.5 phr, 1 phr,3 phr, and 7 phr was found to be the best compounding formulation for the fabricated compound. All of those rubber-based formulations called for the same amount of curing additives, which were as follows: 2.5 phr of sulphur (s), 5 phr of zinc oxide (Zn0), 2 phr of stearic acid, 1 phr of tetraethyl thiuram disulphate (TMTD), and 1 phr of 6PPD. Based on data collected, 3.0 phr of SnO_2, has the highest tensile strength as well as shore hardness value and also better in morphological compared to other composition.

ABSTRAK

Objektif utama kajian ini adalah mengenai sifat mekanikal dan fizikal Getah Asli (NR) bertetulang Timah Dioksida (SnO_2). Timah Dioksida (SnO_2) ialah pengisi berasaskan bukan organik yang digunakan apabila proses sebatian cair digunakan untuk Getah Asli. Timah Dioksida telah dipilih untuk digunakan sebagai agen pengukuhan bagi sifat mekanikal dan fizikal Getah Asli kerana sifat yang dimilikinya yang membolehkannya berbuat demikian. Tujuan utama ini adalah untuk menentukan komposisi Timah Dioksida yang paling berkesan apabila digabungkan dengan Getah Asli. Beberapa ujian, termasuk ujian fizikal dan mekanikal, akan dilakukan ke atas kompaun untuk mengenal pasti sifatnya. Untuk menyiasat ciri mekanikal bahan yang berbeza, ujian tegangan akan dijalankan. Ciri-ciri mekanikal sebatian akan ditentukan menggunakan ujian tegangan dan juga ujian kekerasan Shore. Di bawah Mikroskop Elektron Pengimbasan, struktur sebatian akan dianalisis untuk morfologinya. Gabungan sebatian Getah Asli dan Timah Dioksida berdasarkan 100 phr Getah Asli dan perkadaran timah dioksida (SnO_2) berbeza pada 0 peratus berat(berat%), 0.5 peratus berat(berat%), 1 peratus berat(berat%) ,3 peratus berat(berat%), dan 7 peratus berat(berat%) didapati sebagai rumusan kompaun terbaik untuk sebatian fabrikasi. Kesemua formulasi berasaskan getah tersebut memerlukan jumlah aditif pengawetan yang sama, iaitu seperti berikut: 2.5 phr sulfur (s), 5 phr zink oksida (ZnO), 2 phr asid stearik, 1 phr tetraethyl thiuram disulphate (TMTD), dan 1 jam daripada 6PPD. Berdasarkan data yang dikumpul, komposisi terbaik untuk Getah Asli/SnO_2 ialah 3 phr. Komposisi dipilih berdasarkan kekuatan tegangan tertinggi serta Kekerasan Shore dan juga lebih baik dari segi morfologi berbanding dengan komposisi lain.

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LIST OF SYMBOLS AND ABBREVIATIONS

NR	-	Natural Rubber
SnO_2	-	Tin Dioxide
Phr	-	Per hundred Rubber
UTM	-	Universal Tensile Machine
%	-	Percent
ºC	-	Degree Celcius
OM	-	Optical Microscope
mm	-	Milimmeters
TMTD	-	Tetraethyl Thiuram Disulphate
CBS	-	Sulfenamide
ZnO	-	Zinc Oxide
TCO	-	Transparent Conducting Oxide
kgf/cm^3	-	kilogrammes force per cubic centimetre

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CHAPTER 1

INTRODUCTION

1.1 Background

Rubber is one of the most used types of products in Malaysia given the fact that its price is relatively low, and it is simple to work with. Rubber is put to use in a wide variety of applications in Malaysia, which contributes to the country's increasing production of rubber goods. Along with proteins, carbohydrates, lipids, and inorganic salts, cis-1,4-poly(isoprene) which is Natural Rubber (NR) may be found in significant levels in the milky sap of the Hevea brasiliensis tree. It is undergoing cleaning prosses at first. Then, through acid coagulation, it is separated and processed into sheets (Bokobza, 2019). Because of its very unique qualities, Natural Rubber simply cannot be substituted with synthetic rubber in some applications, such as the production of electrical wire. The primary emphasis of this proposal is placed on the mechanical properties of Natural Rubber reinforced for use as electrical insulators. To enhance Natural Rubber compounds' physical and mechanical properties, study is being conducted to investigate how different kinds of fillers interact with Natural Rubber mixtures. As a consequence of this, the study is focused on the use of Tin Dioxide as filler in compositions of Natural Rubber.

Tin is a group 14 element with oxidation values of +2 and +4 that has several uses including fuel cells and window coatings. It is also widely used in semiconducting and nanowires. Because of its mechanical, optical, and electrical characteristics, researchers are actively doing research on several oxides of tin. In the periodic table, SnO_2 is one of the metal oxides. SnO_2 is used because of its semiconductivity and strong thermal stability. SnO_2

also have 3.6 eV band gap. As a catalyst in the organic synthesis of various compounds, ferroelectric, gas sensing material along with solid electrolyte and inorganic pigment, SnO_2 has been employed in a number of applications.

This study chooses the combination of Natural Rubber modified with Tin Dioxide as the filler using melt compounding method. Tin Dioxide are being choose because of its properties that able to be to strengthen mechanical and physical properties of Natural Rubber. Besides Tin Dioxide is one of the minerals extracted fillers and also environmentally, low cost and friendly nature. Tin Dioxide is globally used mostly in technological applications such as transparent conductors, and high-efficiency solar cells and has primarily been used in the catalyst.

Electrical insulation technology is strongly reliant on cable technology. This requires the development of innovative insulating materials that have a low dielectric loss and also high electrical strength, including the optimization of stress management methods in cable connections and terminations and the development of efficient heat dissipation systems.

1.2 Problem Statement

Insulating materials for electrical cables made from Natural Rubber have been used since the beginning of the electrical industry. Early manufacturers discovered that, in addition to vulcanization chemicals, the benefit of rubber comes from different compounding components, like mineral fillers as well as process aids. Electrical insulation may get degraded over time as a result of the several stresses that it is subjected to, including those that are electrical and mechanical elements. This shortens the material's life span. Nevertheless, mechanical loads pose the greatest risk to insulators. Airborne contaminants

may also pose significant problems since they have the potential to settle on the surface of the insulator, which can result in leakage, dry band arcing, and flashover.(Adupa et al., 2021)

Furthermore, with the price of rubber rising by the day, it is no longer feasible to manufacture a product only from Natural Rubber. In this scenario, the study requires a few components that can be blended with Natural Rubber to make better quality things that meet the consumer's expectations. According to the findings, fillers may be used as an added substance while also improving the properties of Natural Rubber. In improving both mechanical and physical properties, Tin Dioxide can be mixed into the Natural Rubber compound as the fillers.

Tin Dioxide is the mineral extracted that is used as a filler with their characteristic like low cost, good for nature, and because of enhances the properties of the compound. Tin Dioxide as one of the synthesized fillers can be used to improve the application of Natural Rubber through this route has both economic and environmental benefits. This study is about the effect of Tin Dioxide on Natural Rubber through its mechanical properties such as tensile strength and physical properties such as density and microscopy.

1.3 Objective of Study

The main purpose of this study is to identify the mechanical and physical properties of Natural Rubber reinforced with Tin Dioxide. Specifically, the objectives are as follows:

a) To prepare samples of Tin Dioxide with different filler loadings reinforced Natural Rubber for
b) To perform mechanical testing on Tin Dioxide with different filler loadings reinforced Natural Rubber samples.

1.4 Scope of Study

This study is to identify the "Mechanical and Physical Properties of Natural Rubber Reinforced with Tin Dioxide" through the melt compounding method. Moreover, this study focuses on the physical and tensile behaviour of Natural Rubber compound with Tin Dioxide through melt compounding the mixing material using two roll mill mixer followed by various and mechanical testing such as Tensile test, Shore hardness and Scanning Electron Microscope (morphology). The study of this topic can come out with benefits for the surroundings.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will clarify the details of Natural Rubber and filler used to blend with Natural Rubber (Tin Dioxide). This section contains discoveries obtained from literature reviews research, which derived from the books, journal, and article that has the related topic to this study.

2.2 History of Natural Rubber

The pre-Columbian peoples of South and Central America used rubber for a variety of purposes, including the manufacture of balls, containers, and shoes as well as the waterproofing of textiles. Rubber did not pique the curiosity of early European explorers and settlers when it was first discovered. Before the year 1800, intensive research was conducted on the discovery of rubber solvents and the process of waterproofing fabrics. However, rubber was only used for the production of elastic bands and erasers, and these items were manufactured by cutting pieces of rubber that had been imported from Brazil. Joseph Priestley is credited with being the one who first discovered that rubber might be used as an eraser, which is how the material got its name.

Further study led to the discovery of a method that is both practical and effective for waterproofing textiles, as well as the vulcanization process, which fundamentally altered the way the rubber industry operated. Since then, rubber was demanded increasingly due to the expansion of the electrical industry's need for rubber insulation and the development of the pneumatic tyre.

Natural Rubber for electrical insulation has been used since the beginning of the electrical industry. Vulcanization agents found by Charles Goodyear were not the only compounds used by early manufacturers to improve rubber's performance; they also included fillers and process aids. Rubber for electrical insulation was frequently blended with a product created by heating certain vegetable oils with sulphur in a reaction similar to Goodyear's vulcanization process and probably inspired by the same idea. These components, called variously as factice or pitch, are the origins of the term "oil-based rubber," which is frequently used to describe old rubber compounds. A. G. Day began studies in the early 1860s to improve rubber compounds while simultaneously decreasing their cost. He produced "Kerite" after 3,000 tests, which may have been inspired by the Greek term Keros, which means wax. Up until the 1930s, when the first acceptable synthetics were available, Natural Rubber-based electrical insulation was the only polymeric material utilised as a wire and cable dielectric(Zuidema et al., 2011).

The late 19th century development of electrical insulation compounding technology was prompted by the communication and supply requirements of telegraph, telephone, and electrical networks. Samuel Morse created the telegraph in 1837, and the first (air-insulated) telegraph lines were established in 1844 between Washington, DC, and Baltimore, then between Baltimore and Philadelphia in 1846. Telegraph line insulation was difficult, especially if they were to be buried or placed underwater(Zuidema et al., 2011).

2.3 Natural Rubber

Both natural and synthetic sources may be used in the production of rubber. Natural Rubber is derived from the milky white fluid known as latex, which may be found in a number of different plants. However, the tree Hevea brasiliensis is the only significant

commercial source of Natural Rubber (Figure 2.1). After being sheeted, extruded in unique forms, coated as a coating, or moulded, the compounded rubber goes through the vulcanization process.

Figure 2.1 Rubber tree (Hevea *brasiliensis)*

When compared to vulcanised rubber, uncured rubber has a much less number of applications. It is also used to make crepe rubber, which is used in the production of insulating blankets and footwear, in addition to adhesive and friction tapes, and cements. On the other hand, vulcanised rubber may be used in many fields of applications. Because of their resistance to abrasion, gentler types of rubber are useful for the treads of vehicle tyres and conveyor belts, while harder types of rubber are useful for pump housings and pipework used in the handling of abrasive sludge.

Rubber's flexibility allows it to be used in hoses, tyres, and rollers for a wide variety of devices, ranging from domestic clothes wringers to printing presses; rubber's elasticity makes it suitable for various kinds of shock absorbers and for specialised machinery mountings designed to reduce vibration(Ismail et al., 2011). Rubber's ability to resist the passage of gases makes it an excellent material for use in the production of products like air hoses, balloons, balls, and cushions, among other things.

The rubber's resilience to water and its ability to repel from the majority of fluid chemicals has led to its use in rainwear, diving gear, chemical and medical tubing, as well

as the liner for storage tanks, processing equipment, and train tank cars. In addition to having an electrical resistance, the rubber may be used in the production of soft rubber items such as insulation and protective footwear, gloves, and blankets. Because of its durability, hard rubber is often used in the manufacturing of goods such as telephone housings, components for radio sets, metres, and several other types of electrical equipment. Rubber's friction, which has a high coefficient on dry surfaces but a low coefficient on wet surfaces, enables it to be used for power-transmission belting as well as for water-lubricated bearings in deep-well pumps in order to create a good seal.

Rubber compounding is the process of adding compounding materials and the quantity to blend to produce the best rubber formulation that can be processed, meets or exceeds related product requirements, and can be cost-friendly. This process involves both the fine art and the scientific study of compounding.

Table 2.1 Generalized rubber Compound

Ingredient	***phr***
Natural Rubber	100
Filler	50
Softener	5
Antioxidant	1
Stearic acid	1
Zinc oxide	5
Accelerator	1
Sulfur	2
Total	*165*