PREPARATION AND CHARACTERIZATION OF SiR/EPDM FILLED WITH WASTE GLASS POWDER (WGP) RUBBER BLEND COMPOSITES

Submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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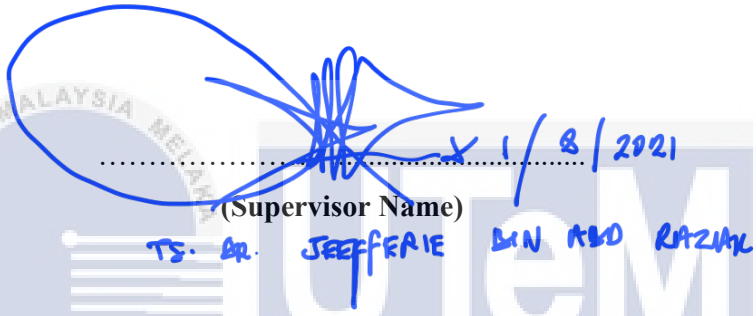
APPROVAL

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:



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ABSTRAK

Adunan getah silikon (SiR) dan getah *Ethylene Propylene Diene Monomer* (EPDM) telah dipilih secara meluas bagi aplikasi penebat voltan tinggi (HV). Kelebihan yang ditunjukkan melalui kombinasi ini adalah seperti meningkatkan sifat mekanik penebat dengan kestabilan terma yang jauh lebih tinggi dan rintangan terhadap voltan tinggi. Adunan getah SiR / EPDM juga memberikan ciri ringan, meningkatkan sifat elektrik dan kekuatan lenturan. Penyelidikan ini dijalankan bagi menyediakan dan menilai ciri dan prestasi adunan komposit getah SiR / EPDM yang diperkuat dengan pengisi serbuk sisa kaca. Pengisi itu adalah berasal dari sisa kaca sebagai sumber SiO_2. Kira-kira 0, 10, 20, 30 dan 40% berat serbuk sisa silika kaca ditambah ke dalam formulasi aduan getah SiR / EPDM bagi pembuatan komposit SiR / EPDM- SiO_2. Kesan penambahan pengisi tersebut dinilai dari aspek prestasi mekanikal dan fizikal mereka. Penemuan ini, membuktikan potensi sisa kaca silika sebagai pengisi berfungsi yang bermanfaat apabila keputusan ujian mengenalpasti bahan mentah XRD,PSA dan SEM mennjukkan sifat sebenar kaca yang amorf, bersaiz lingkungan 60-90 μm dan berbentuk berpanjangan dan bersudut yang memudahkan ia menjadi pengisi adunan SiR / EPDM untuk aplikasi HV yang luar biasa. Adunan SiR/EPDM dan sisa kaca pada berat 30% menunjukkan kesan paling positif apabila keputusan kekuatan tegangan dan pemanjangan utama membuktikan ianya komposisi terbaik dengan nilai 6.2MPa dan 531.5%.Ini jelas menunjukkan sisa kaca merupakan kombinasi terbaik untuk adunan getah SiR/EPDM sebagai penebat terhadap voltan tinggi.

ABSTRACT

Silicone rubber (SiR) and Ethylene Propylene Diene Monomer (EPDM) rubber blends have been widely selected for high voltage (HV) insulating applications. The advantages shown through this combination are such as improving the mechanical properties of the insulator with much higher thermal stability and resistance to high voltages. SiR / EPDM rubber blends also provide lightweight properties, improving electrical properties and flexural strength. This research was conducted to prepare and evaluate the characteristics and performance of SiR / EPDM rubber composite blends reinforced with glass waste powder filler. The filler is derived from glass residue as a source of SiO_2. Approximately 0, 10, 20, 30 and 40% by weight of glass silica waste powder were added into the SiR / EPDM rubber complaint formulation for the manufacture of SiR / EPDM- SiO_2 composites. The effect of the addition of such fillers is evaluated from the aspect of their mechanical and physical performance. This finding, proves the potential of silica glass waste as a useful functional filler when test results identify XRD, PSA and SEM raw materials show the true properties of amorphous glass with size range 60-90 μm and elongated and angular shape that facilitates it to be SiR / EPDM for exceptional HV applications. SiR/EPDM blends with glass waste at 30% showed the most positive effect when the main tensile strength and elongation results proved to be the best composition with values of 6.2MPa and 531.5%. This clearly shows that glass waste is the best combination for SiR/EPDM rubber blends as high voltage insulator.

DEDICATION

To my beloved father, Abu Hassan bin Sobiran

My appreciated and one and only mother, Habibah binti Yusof

My adorable siblings, Azizul,Azrul,Azhar,Azizul,Nora,Piza

For giving me moral support, money, cooperation, encouragement and understanding

Thank You So Much & Love you to the moon and back

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LIST OF ABBREVIATIONS

SiR	-	Silicone Rubber
HV	-	High Voltage
SiO_2	-	Silica
EPDM	-	Ethylene Propylene Diene Monomer
UV	-	Ultra Violet
CFL	-	Compact Fluorescent Lamp
PSA	-	Particle Size Analyzer
XRD	-	X-ray Diffraction Analysis
SEM	-	Scanning Electron Microscope
CE	-	Cycloaliphatic Epoxy
PDMS	-	Polydimethylsiloxane
CNTS	-	Carbon Nanotubes
HTVSR	-	High-Temperature Vulcanized Silicone Rubber
GNR	-	Graphene Nanoribbon
DBA	-	Dry Band Arcing
ASTM	-	American Society for Testing Materials
IRHD	-	International Rubber Hardness Degree
IPT	-	Inclined Plane Tracking
AC	-	Alternative Current
DC	-	Direct Current
phr	-	Parts per Hundred Rubber
WGP	-	Waste Glass Powder

LIST OF SYMBOLS

Ω	-	Ohms
wt	-	Weight
%	-	Percentage
cm	-	Centimetre
kV	-	Kilovolt
mm	-	Millimetre
mg	-	Milligram
W	-	Watt
°	-	Degree
°C	-	Degree Celsius
Mpa	-	Megapascal
SG	-	Specific Gravity

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Electrical insulation is regarded as a significant criterion to be recognized for high voltage applications. In the last few years, many classifications of high voltage insulators have been produced for outdoor transmission lines. In the 20th century, the history of high voltage insulators has started with porcelain as the only material used for high voltage isolation purposes. The needs for replacement were to minimize the use of expensive porcelain products to reduce production costs and most importantly, to improve the tracing and corrosion resistance of insulator (Khan et al., 2017). Due to its hydrophobic properties, polymer material was chosen to replace previous insulator types which support the dry band arcing phenomenon which resulted in flashing phenomena (Prasenjit et al., 2015). Polymer also have light weight and flexible features that make it easier to erect and operate isolators even at the remote areas, including resistant to vandalism (Xuguang et al., 2000).

Today, polymer-based isolators are rising in most countries due to technological development and attractive potential benefits for their end users (Ramirez and Hernandez, 2016). Since polymer insulations are well accepted for high voltage application, many researchers worldwide have carried out huge number of major academic and practical activities to improve the high voltage effectiveness. Tracking and erosion are critical things to consider as it contributes to a stronger insulating strength (Kannan et al., 2015). Furthermore, the hydrophobicity property of polymeric insulators is ideal for the use in polluted environments.

This kind of properties are required for the use of polymer insulating material. However, the polymeric based isolators also have several limitations and weaknesses.

If the polymer insulator agonizes for a long time from monitoring and erosion, it can cause the debacle in the insulator (Yaacob et al., 2013). Therefore, an effort should be taken to solve these problems. Since silicone rubber (SiR) had a lower stiffness, some practical fillers have been purposely added in order to increase the resulting electrical isolation and mechanical strength for polymer-based composites (Amin and Salman, 2006). As many previous researchers have stated, the addition of functional fillers to the polymer matrix could boost some properties enhancement and also could reduce the costs of production process (Ali et al., 2017).

Polymer-based composite insulators have increased demand in recent years and have been recognized worldwide (Momen and Farzaneh, 2011). According to Rowland et al. (2010) The failure of polymer composite insulators is due to inadequate design and incorrect production processes that normally will prematurely occur. To address these advantages, a full understanding of their function and involvement of synthetic and mineral fillers is still to be realized. It should be noted that the contribution of filler in polymer composite was significant in HV application as it could increase the mechanical strength and other electrical isolation attributes of the resulting polymer composites (Bian et al., 2013). In general, fillers or reinforcement material are often used to enhance based polymer properties and to reduce the final cost of final products (Aman et al., 2013).

For this study, the blending between ethylene propylene diene monomer (EPDM) and silicone rubber (SiR) with the selected fillers of waste silica glass (SiO_2) filler were evaluated. Previously, silicone rubber industries had become extremely commercialized and covering a wide range of uses, including cable applications and insulation pads (Hamdani, 2010). Incorporating silicone rubber with fillers had driven the market from scientific and common industries. SiR rubber was also known for its great electrical and mechanical properties, despite of good hydrophobicity on the surface and was the key choice for high voltage applications (Du et al., 2011). As for EPDM rubber, it is well known as excellent water resistant along with very good with ozone, UV and oxidation for resistance (Martin, 2015). Blending of SiR with EPDM rubber could complement the weakness of each rubber phases.

In addition, fillers or reinforcement material are added to the rubber blend to improve the polymeric composite characteristics and also to decrease the final cost of final products (Aman et al., 2013). The most common filler is calcium carbonate and silicas for the electrical high voltage insulation. In this study, the full focus is to add on the waste glass as fillers as it contents the silicon (SiO_2) component. To be more intriguing, the raw material used was obtained from the waste resources. Disposing glass waste material also an issue in waste management. Difficulty was occurred in disposing solid waste via land-filling due to most of land-fills had already exceeded its maximum volume (Manaf et al., 2009).

This problem has been the main reason for companies and researchers around the globe to develop an improve technologies to reduce or eliminating the waste glass as industrial or domestic wastes (Thoo et al., 2013). This can be one of practical way of recycling activity as the environment issues faced by this country. Furthermore, the waste glass is used as silica, which has higher particular surface, is primarily due to the probability of increasing the number of silica bonds with the elastomer and thus increasing the amount of reinforcement of the silica (Olivier Durrel, 2008). Also, it will enhance the properties of composites to be used as the best candidate high voltage insulation purposes.

To decide whether or not such materials are used for high voltage insulators few criteria must be met. The material was considered to have failed according to BS: EN 6085 standard, if the tracking duration on the material's test surface was 2.50 cm. Thus, the effects of the waste glass powder loadings in SiR/EPDM rubber blend matrix to the mechanical and physical properties were further evaluated in this study.

1.2 Problem Statement

The problem in preparing the SiR/EPDM rubber as a matrix and waste glass fillers as a strengthening component are related with SiR/EPDM rubber matrix and SiO_2 filler powder interaction, due to improper mixing. The quantity and accuracy of the filler added would be a prime challenge since the right one is remains unspecified. The smallest size of fillers could cause problems of non-homogeneous dispersion, and could typically lead into inhomogeneity of interaction and distribution due to higher surface energy, which could then result into

inhomogeneous filler dispersion. The research also has enormous effort to make the waste glass filled SiR/EPDM as one of the versatile and sustainable insulators for high voltage applications.

For high voltage applications, an effort has been made to recycle waste resource of the waste glass to be incorporated in SiR/EPDM rubber blend, for the high voltage (HV) electrical insulation application. Hence, the heat resistance and mechanical strength behavior of produced SiR based composites are crucially important. Recycling of waste glass as a filler source has been a novel attempt to monitor its potential output when combined with SiR/EPDM rubber matrix for high voltage insulation purposes. Researchers have learned more about recycling the waste capital because it can save the world from overwhelmed disposal waste. In addition, plenty of waste glass was generated annually but the recycling effort has still very low. This has motivated us to develop the sustainable rubber blend composites which utilizing waste filler for better electrical insulation, thermal resistance and superior mechanical strength and physical properties.

On the use of high-voltage insulators, it was good for the fabricated composites to have a better hydrophobic surface as it could minimize the leakage current that caused total failure (Prasenjit et al., 2015). Thus, in this study, a focus has been given to evaluate the result mechanical and physical performances of SiR/EPDM with different waste glass filler loading which will effects for the purpose of high voltage (HV) insulator application.

1.3 Objectives

1. To characterize the waste glass powder (SiO_2) as rubber blend composite filler by using a Particle Size Analyzer (PSA), Scanning Electron Microscope (SEM) and X-ray Diffraction Analysis (XRD) methods.

2. To evaluate the effects of waste glass powder (SiO_2) filler loading to the mechanical and physical properties of SiR/EPDM rubber blend composites.

1.4 Scope of Works

This research has been performed to focus on the preparation and testing of silicone rubber with ethylene propylene diene monomer-based composites filled with waste glass powder as filler, for use of high voltage insulators. At an early point, the fillers are extracted from the waste capital of waste glass bottle. The technique used is basically manual crushing and ball milling in order to obtain finer powder particles. Particle size analysis (PSA) machine was used to analyse the size range of produced powder particles while the XRD observation to understand further their morphological behaviour of waste glass powder (WGP) fillers.

The SiR/EPDM with fillers composites are then successively prepared by using an open two roll mill for compounding process and has been cured by using a peroxide-based vulcanization technique through a hot compression process. The filler formulations that being added into SiR/EPDM blend matrix are in the composition of 0 wt.%, 10 wt.%, 20 wt.%, 30 wt.% and 40 wt.% of SiO_2 waste glass powder filler loadings. Mechanical tensile testing was conducted to the composite samples for tensile strength and elongation of break (EAB) determination. Other tests like hardness tests (Shore A) are basically conducted to determine the physical behavior of developed SiR/EPDM-based rubber blend composites with different SiO_2 filler loadings. The resulted mechanical tensile strength and physical properties of SiR/EPDM based composites are to comply the entire stated research objectives of this study.

1.5 Significance of Research

Numerous advantages can be gained after the completion of this research. The first thing that can be relevant is the properties enhancement of polymeric materials in order to sustain the HV exposure. Therefore, this study was performed to enhance the mechanical and physical characteristic of ethylene propylene diene monomer and silicone rubber as insulation materials with a special focus on improving the endurance and mechanical strength at the high voltage exposure. The filler is taken from the waste source of used glass bottle to comply with the green and sustainable environmental concept of waste recycling.

In Malaysia, the key explanation for the selection of waste source filler is to support the sustainable production of industrial materials. Recycling efforts was world-famous for attempts to reduce the problem of waste disposal and recycling costs. The benefit of using composite materials will also reduce the costs and weight for the resulting composites materials. Composite materials have also been shown to be able to tackle the material weakness primarily due to the intrinsic filler added. This was an attempt to propose new high voltage insulation materials by using a sustainable material. In the near future, the final product and the results of this research could provide the potential of cost-effective alternative and recyclable improvements for the high voltage (HV) polymer composites as a replacement for ceramic-based porcelain insulators.

1.6 Thesis Organization

The overall organization of this thesis is including of five main chapters, as it starts with an introductory chapter. For chapter 1, it had discussed on the background of study and the problems statement that are identified through multiple searches by using previous journals, articles and current news. It was then followed by the objectives that is set to be achieved according to the resource scope which narrows down the area of study. Several scope revision has been made in accordance to uncertain current COVID-19 pandemic situation.

Chapter 2 begins with reviewing the material revolution that being used for high voltage application and followed by the overall explanation pertaining to the silicon rubber which will be used throughout of this research. Then, the ethylene propylene diene monomer, also being discussed. Furthermore, the most highlighted part in this research is the waste glass explanation which to be utilized as fillers. Also, the rubber blend composite application is being discussed in a way to understand the rubber blend system. Last but not least, the high voltage testing and its performance study were also being explained.

Chapter 3 has described the materials, methods and procedures applied to achieve the objectives mentioned in this study. The flow starts from explaining the materials used, and the methods used to compound raw materials into a hybrid composite. This is followed by the analysis or experiments to determine the structure and the exact composition of silicon rubber and ethylene propylene diene monomer with the waste glass powder as filler.

Chapter 4 discussed the experiments results and data collected throughout the experiments after conducting the methods and procedure mentioned in Chapter 3. The raw material characterization testing which include SEM, XRD and PSA. Followed by the mechanical and physical testing of the composites. Chapter 5 summarizes the ensure results related to mechanical and physical testing for the of SiR/EPDM filled with waste glass powder-based rubber blend composites.