UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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FABRICATION OF ACTIVATED CARBON FILLED EPOXIDIZED NATURAL RUBBER COMPOSITE VIA SOLVENT CASTING METHOD

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons.)

by

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This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) (Hons.). The member of the supervisory is as follow:

……………………………….

(Dr. Mohd Asyadi `Azam Bin Mohd Abid)

DECLARATION

I hereby, declared this report entitled "Fabrication of Activated Carbon Filled Epoxidized Natural Rubber Composite via Solvent Casting Method" is the results of my own research except as cited in references

Signature	:	………………………………………….
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ABSTRAK

Disebabkan pengubahasuaian bahan dengan menggabungkan mereka dengan satu sama lain untuk mengeksplotasi ciri-ciri yang unik di mana pelaksanaan bahan dipertingkatkan menjadi matlamat utama untuk diketahui. Walaupun penggunaan bahan pengisi nano selalu dilakukan, tetapi kewujudan bahan pengisi mikro mungkin member potensi dalam komposit polimer. Maka, kajian ini berharap untuk memfabrikasi karbon teraktif (AC) diisi epoxidized getah asli (ENR) composite melalui kaedah pemutus pelarut dan cirri-ciri yang direka AC diisi ENR composite dari sudut sifat mekanikal (tegangan) dan morfologi. Dalam kajian ini, komposit polimer terdiri daripada ENR sebagai matriks dan AC sebagai pengisi di mana pembebanan pengisi yang berbeza dalam julat 0 hingga 7 phr telah digunakan untuk menghasilkan komposit. Selain itu, kajian ini bertujuan untuk mengkaji kesan AC pada sifat-sifat mekanikal, penyebaran pengisi dan interaksi antara pengisi dan matriks dengan menggunakan kaedah pemutus pelarut. Kesan kekurangan dan kebaikan dari komposit telah dikenal pasti dengan menjalani pelbagai ujian seperti ujian tegangan, ujian ketumpatan sambung silang, ujian penyerapan air dan ujian kepadatan. Mikroskop pengimbas elektron (SEM) juga telah akan digunakan untuk menganalisis morfologi permuakaan patah. Secara keseluruhannya, keputusan menunjukkan peningkatan yang tinggi dari segi sifat mekanik dengan menambah AC dalam ENR matriks tanpa pengumpalan yang jelas yang menunjukkan bahawa pengagihan yang baik oleh pengisi dalam ENR. Oleh itu, penggunaan AC sebagai pengisi boleh menghasilkan sifat-sifat yang sama seperti bahan karbon mahal seerti CNT dan graphene dan dengan itu ia akan mengurangkan kos.

ABSTRACT

Owing to the modifications of materials is by combining them with one another to exploiting their unique characteristic where the implementation of enhanced materials being the ultimate goal to be known. Despite of often using nanofiller materials, the existence of microfiller material may be give a potential in polymer composite. Therefore, this research means to fabricate activated carbon (AC) filled epoxidized natural rubber (ENR) composite through solvent casting method and to characterize fabricated AC filled ENR composite from the view point of mechanical (tensile) and morphological properties. In this research the polymer composite composed of ENR as the matrix and AC as the filler where different filler loading in the range 0 to 7 phr was used to fabricate the composites. Moreover, this research is intended to investigate the effects of AC loading on mechanical properties, filler dispersion and the interaction between filler and matrix by using solvent casting method. Drawback and advantageous effects of the composite has been identified by undergo various testing like tensile test, crosslink density test, water absorption test and density test. Scanning electron microscopy also has been employed to analyse the morphology of the fractured surface. Overall, the results show high improvement in mechanical properties by adding AC in ENR matrix with no obvious agglomeration that indicates a good distribution of fillers in ENR. Therefore, the use of AC as a filler may produce the same properties as others expensive carbon materials such as CNT and graphene and thus it will reduce the cost.

DEDICATION

Dedicated to my beloved parents, my father Mr.Hj. Hassan Bin Mohamad and Mrs.Hjh Azizah Binti Md Daud special thanks for your boundless love and repeated encouragement. To my siblings, friends, lecturer and supervisor.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AC	-	Activated Carbon
ASTM	-	American Society of Testing and Materials
C	-	Carbon
CNT	-	Carbon Nanotube
ENR	-	Epoxidized Natural Rubber
GnP	-	Graphene Nanoplatelets
MWCNT	-	Multiwalled Carbon Nanotube
SEM	-	Scanning Electron Microscopy
SWCNT	-	Single Walled Carbon Nanotube
XRD	-	X-Ray Diffraction
˚C	-	Celcius
Phr	-	Parts per Hundred
kPa	-	Kilo Pascal

CHAPTER 1

INTRODUCTION

1.1 Background

As worldwide technologies and engineering methodologies become ever more refined and redeveloped, the need for absolute control over all aspects of physical systems become more increasingly obvious (Boyles *et al*. 2011). In order to reap all the benefits of composite materials, it is importance and must for the future engineers to exposure the topic at early stage of education. Therefore, the modifications of materials by combining them with one another and exploiting their individually unique characteristics for the purpose of producing physical responses to those found in nature is the ultimate goal where the implementation of enhanced materials is not only a curiosity, but a necessity (Boyles *et al*. 2011).

Composites are materials that have existed for millennia and are common both in nature and among engineering materials. Moreover, polymers are popular with their excellent processability, lower cost and also low specific gravity. In contrast, the stiffness and strength were quite low compared to metals and ceramics, but their high strength to weight ratio their ability to be processed at lower temperature enabled them to replace metals and ceramics in numerous applications. Thus, to overcome these drawbacks, polymers are used as composite to improve the performance and cost effectiveness. Composites exhibits physical properties synergically derived from both polymer and the filler. There are three types of composite which are polymer matrix composite (PMC), metal matrix composite (MMC) and ceramic matrix composite (CMC). Polymer composites have mechanical and heat resistance properties superior to pristine polymer. Polymer nancomposite is one of the types of composite materials in which nananoscopic inorganic particles, typically 10-100Å are dispersed in an organic polymer matrix in order to improve the performance properties of the polymer (Lagashetty and Venkataraman, 2005). This type of composite represents a new alternative to conventionally foiled polymers where the filler dispersion nanocomposites show significantly improved properties when compared to the pure polymers. Early research on polymer nanocomposites are focused on development of nanoclay filled thermoplastic systems. Then, research diversified into other polymers systems like thermosets and elastomers and nanofillers like nanosilica and CNT.

As a matrix material, epoxidized natural rubber (ENR) have found commercial applications in a wide range of areas, e.g. their hysteresis properties are utilized in both mechanical and acoustic damping devices and in specialty shoe to give high wet grip. ENR also are used in the construction of composites conveyor belts because of their adhesive properties. The combination of high strength and low resilience of ENR based conveyor belts are advantages under service conditions (Gelling, 1991).

Nowadays, fillers such as graphene and CNT show superior properties that shows dramatic significance among materials scientists for developing nanocomposites. The first polymer nanocomposite using CNT as fillers were done by Ajayaan *et al.* (1994). Since then, there have been research related to processing and resulting mechanical and/or electrical properties of fabricated polymer nanocomposite. Besides graphene, single-walled carbon nanotube (SWCNT) as a filler in rubber nanocomposite shows a great deal of attention (Talib *et al.* 2012). The reinforcing effect of filler depends on the interfacial structure between the polymer and the filler. As the size of the filler reduces, the surface area reduces and consequently, the interface between the filler and the polymer increases.

However, the introduction of microstructure size material filler such activated carbon (AC) attract the attention where it poses excellent adsorption performance and development pore structure which gives superiority where it has been extensively utilized in different fields such as environmental protection, catalysis, food, pharmacy and etc. (Yan-Qing *et al.* 2012). Activated carbon also has a reasonable price compare to others carbon material.

Furthermore, activated carbon material that comes from a family of highly carbonaceous perhaps is the most important type of industrial carbon material (Verla, *et al.* 2012). This material is prepared by carbonization and activation of a large number of raw materials of organic such as wood, coal, and lignite where the method of activation, physical and chemical properties of the raw materials is a factor to a characteristic of activated carbon. (Lua and Guo, 2001).

In processing elastomer nanocomposites, various techniques can be applied such as latex blending solution mixing, internal mixing and open mill mixing. In addition, nano and micro-structured functional materials have been predicted to be excellent functional material candidates for catalysis, solar cells, rechargeable batteries, sensors and etc. which have received significance attentions due to many excellent properties and desired requirement.

Consequently, the main effort of the research is to come out with selecting the activated carbon as fillers in order to fabricate superior properties of polymer composite. The activated carbon will reinforced with ENR and will be characterized to look out in terms of their fabrication process and properties. It is expected to increase the properties of polymer composite with high mechanical strength.

1.2 Problem Statement

This research is aiming on the fabrication of activated carbon filled ENR composite through solvent casting method. Hence, the studying of this research will show the properties of composite that might be give a significant improvement and new finding to existing composite materials.

From previous research by Toyota in 1990, nanofillers were applied as the earliest application where nanoclay composites are used in their automobiles. There are several alloptropes of carbon such as graphite, diamond, and amorphous carbon where their physical properties are different widely. As potential nanofiller at a low loading, graphene shows an attractive material that can spectacularly improve the properties of polymer-based composites (Du and Cheng, 2012). Research that have been done so far shows that graphene polymer composites are shows potential multifunctional materials with significantly improved tensile strength and elastic modulus, electrical and also thermal conductivity.

However, some results have been compared with CNT/polymer composites which the properties are scattered and even lower than for CNT/polymer composites. This might be due to many factors, including the type of graphene used, dispersion state of graphene in the polymer matrix and its interfacial interaction. Besides, the amount of wrinkling in the graphene and network structure in the matrix also can affect the properties of graphene/polymer composites (Du and Cheng, 2012)**.** Uniformly dispersed fillers can improve mechanical and electrical properties and these can also be useful in producing advanced polymer composites. Though the use of nanofiller material shows a dramatically enhancement but the existence of microfiller material may shows a significant improvements towards polymer composite.

The critical issue that usually appear is the dispersions of filler in a polymer matrix which is because of the strong metallic bonding force state by Das, 2012 (RozpAlocha *et al*. 2007) and Van der Waals interaction (Coulson and Valence 1965) between graphene platelets thus make it difficult to disperse in polymers. The same goes to multi-walled CNT, the contact area between the two tubes is relatively much smaller (RozpAlocha *et al*. 2007). A highly need for good dispersion of these nanostructures in a polymer matrix where the dispersion of CNT and graphene need to be enhanced. This is because they have a tendency to agglomerate in nanocomposites which may affect the properties of the composite.

In the last few decades show increasing technology that requires the use of activated carbons in a wide range of application involving adsorption. An example such as plastics, the reinforcement shows an increase in modulus and hardness where the effect of particulate fillers is quite clear where they replace a part of matrix and makes modulus becomes higher, but deformation at break decreases in the same time. Due to higher glass transition temperature of ENR, some mechanical properties of ENR such as tensile and fatigue behaviour, damping properties, and wet grip are expected to be better than of natural rubber (Gelling *et al.* 1988).

The incorporation of activated carbon into natural rubber will study the mechanical properties. Besides, it is it was found that there is no studied have involved the preparation and characterization of AC/ENR composites. Therefore, this research intends to look out the potential properties of activated carbon as filler in improving the properties of polymer matrices on different percentage of composition, such as the mechanical and microstructural properties. Activated carbon is one of the basic carbon materials that easily produced and cost at reasonable price which makes it a worth material for further research investigation.

In order to get improvements in strength and stiffness in nanocomposite of ENR, elastomers are recommended reinforced with mineral fillers because the rubber formulation would yield resilient products that having elastic properties but little strength. In term of processing, blending of two or more types of polymer is a useful technique for preparation and developing materials with better-quality (Sikong *et al*. 2009). Besides that, stable dispersion of activated carbon and ENR is possible. The extent of property improvement depends on several parameters including the size of the particles, aspect ratio, degree of dispersion and orientation in the matrix and also the degree of adhesion with the rubber chains.

A suitable technique for fabrication process is through solvent casting method is a good method to get a good mixing and proper dispersion between the filler and the matrix. The most common method for preparing polymer CNT composites by mixing the CNT and polymer in a suitable solvent before evaporating the solvent to form a composite film. The benefits of this method is that agitation of the CNT powder in a solvent improved the dispersion of CNT (Beyou *et al*. 2013). Besides, the used of this method may avoid contaminants that can be the obstruction in fabricating polymer composite.

Thus, the used of activated carbon as a filler in this research may create an improvement properties of polymer composite. The use of solvent casting method, composite compound formulation, dispersion of filler and adhesion between the filler and the matrix of AC/ENR composite are also studied.

1.3 Objective

The objectives of this research:

(a) To fabricate activated carbon filled epoxidized natural rubber (ENR) composite via solvent mixing method.
(b) To characterize fabricated activated carbon filled ENR composite from the view point of tensile and morphology properties.

1.4 Scope of Study

The scopes of the research are based on the objectives:

(a) The study dispersion of filler in rubber using solvent casting method (Objective 1).
(b) The filler dispersion and the interaction between filler and matrix (Objective 1).
(c) The study of mechanical behaviour and microstructural evolution on the polymer composite (Objective 2).
(d) Mechanical and microstructural properties of polymer composites (Objective 2).

1.5 Report Organization

This report will be divided into five major chapters:

I. Chapter 1: Introduction

This chapter will explain about the background, problem statement, objectives, and scopes of the study.

II. Chapter 2: Literature review

This chapter will explain with more details of the study by referring journals, books or website as sources of the information.

III. Chapter 3: Methodology

This chapter is describing the steps on how this study is conducted by making a flow chart of the study. It is also explain the procedures of the study that is useful and be as a guideline in order to make the project run smoothly and properly. This chapter is highly important where it is one of the preparations step for PSM II.

IV. Chapter 4: Result and Discussion

This chapter is presents the data and results obtained through all testing and and analysis.

V. Chapter 5: Conclusion and Recommendation

Concludes the result of study and provides recommendations for future improvement.

CHAPTER 2

LITERATURE REVIEW

This chapter explained further reviews about the fundamental and component of this research that will help in order to answer the objectives for this research. Throughout this literature review, the types of several carbon materials will be exposed in detail in term of structure, properties, and application that will be fabricated with natural rubber based on their performance. Then, the next part will discuss the result comes out from the experimental done in characterizing fabricated of carbon material filled natural rubber composite.

2.1 Composite

Nowadays, the needs of high performance materials such as composite are increase due to the rapid development in manufacturing. Even though composite are generally more expensive in comparison to traditional construction materials, and not widely used in many constructive and building activities, but their advantage of being lightweight, more corrosion resistant and stronger makes them interesting. Moreover, the volume and number of applications of composite materials has grown steadily, penetrating and conquering new markets. Modern composite materials constitute a significant proportion of the engineered materials market. The wide variety of behaviours which may be exhibited by rubber materials, their use in the development of structures having to respond to suspension and absorption tasks is becoming more widespread (Devries, 1998). Therefore, in order to extend the range of the use of such materials, the adding reinforcements inside them is required, improving their strength.