UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

PHYSICAL-MECHANICAL PROPERTIES OF PALM KERNEL ACTIVATED CARBON-EPOXY (PKAC-E) COMPOSITE

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Master of Mechanical Engineering

(Applied Mechanics)

2016

PHYSICAL-MECHANICAL PROPERTIES OF PALM KERNEL ACTIVATED CARBON-EPOXY (PKAC-E) COMPOSITE

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A dissertation submitted
in fulfilment of the requirements for the degree of Master of Mechanical Engineering (Applied Mechanics)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

I declare that this dissertation entitled "PHYSICAL-MECHANICAL PROPERTIES OF PALM KERNEL ACTIVATED CARBON-EPOXY (PKAC-E) COMPOSITE" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Ahmed Qays Khudhair

Date : 9/9/2016

APPROVAL

I hereby declare that I have read this dissertation and in my opinion this dissertation is sufficient in terms of scope and quality for the award of Master of Mechanical Engineering (Applied Mechanics).

Signature :

Supervisor Name: Assoc. Prof. Dr. Mohd Fadzli Bin Abdollah

Date : 9 / 9 / 2016

DEDICATION

This dissertation dedicated to my lovely family

ABSTRACT

Palm kernel activated carbon-Epoxy (PKAC-E) composite possess good properties to function as a self-lubricated material in the dry sliding conditions. However, there are no previous studies have focused on the physical-mechanical properties of this composite. In this study, the effect of PKAC composition on the physical-mechanical properties of the composite was investigated. The polymer resin was reinforced with 65%, 70%, and 75% by weight of PKAC and compacted into a die at 70°C with 20-ton pressure for 15 minutes by using compaction technique. The specimens were prepared to conduct tensile, hardness, porosity, density, and water absorption tests. It was observed that the most interesting properties for PKAC-E composite have found in the hardness and density tests. The properties of PKAC-E composite 65-35% were better than other two composites 70-30% and 75-25% in terms of high hardness and low density, while the PKAC-E composite 70-30% was slightly better in terms of tensile strength properties. In addition, the PKAC-E composite 65-35 % has proved its superiority in terms of hardness and density properties with other synthetic-natural reinforced polymer composites. PKAC-E composite with the optimum properties has high hardness, lightweight, low-cost and can be very useful for further industrial applications and other machinery parts.

ABSTRAK

Komposit karbon teraktif kelapa sawit (PKAC-E) mempunyai ciri-ciri yang baik untuk bertindak sebagai pelincir kendiri dalam keadaan gelongsor kering. Walau bagaimanapun, tiada kajian sebelum ini yang memberi tumpuan kepada ciri-ciri fizikal-mekanikal pada komposit ini. Dalam kajian ini, kesan komposisi PKAC kepada sifat-sifat fizikal-mekanikal komposit tersebut telah dikaji. Resin polimer telah diperkukuhkan dengan 65%, 70%, dan 75% mengikut berat PKAC dan kemudian dipadatkan ke dalam acuan pada 70°C dengan tekanan 20-tan untuk 15 minit dengan menggunakan teknik pemadatan. Spesimen disediakan untuk menjalankan ujian tegangan, kekerasan, keliangan, ketumpatan, dan ujian penyerapan air. Ciri-ciri istimewa komposit PKAC-E telah diperhatikan dalam ujian kekerasan dan kepadatan. Pada komposisi 65-35%, komposit PKAC-E adalah lebih baik daripada dua komposit lain 70-30% dan 75 -25% dari segi kekerasan yang tinggi dan ketumpatan yang rendah, manakala komposit PKAC-E 70-30% adalah lebih baik dari segi kekuatan tegangan. Di samping itu, komposit PKAC-E 65-35% telah membuktikan keunggulannya dari segi kekerasan dan ketumpatan dengan komposit polimer sintetik-semulajadi yang lain. Komposit PKAC-E dengan sifat-sifat yang optimum mempunyai kekerasan yang tinggi, ringan, kos yang rendah dan boleh menjadi sangat berguna untuk aplikasi perindustrian lanjutan dan bahagian-bahagian jentera lain.

ACKNOWLEDGEMENTS

I am grateful to Allah who gave me courage, patience and strength to carry out this work. I would like to thank Allah for giving me the opportunity to live, for being the person that I am and for his guidance and protection throughout my life.

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Assoc. Prof. Dr. Mohd Fadzli Bin Abdullah from the Faculty of Mechanical Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this dissertation.

Special thanks to all my colleagues, my beloved mother, father, and siblings for their moral support in completing this degree. Lastly, thanks to everyone who had been associated with the crucial parts of the success of this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	Activated Carbon
PKAC-E	Palm kernel Activated Carbon-Epoxy
C-C	Carbon-Carbon
PMC's	Polymer Matrix Composites
MMC's	Metal Matrix Composites
CMC's	Ceramic Matrix Composites
RTM	Resin Transfer Mouldings
GRP	Glass fibre Reinforced Plastics
DMC	Dough Molding Compounds
BMC	Bulk Molding Compounds
CFM	Continuous Filament Mat
CSM	Chopped Strand Mat
CFRP	Continuous Fibre Reinforced Polymer
AFM	Atomic Force Microscopy
CVI	Chemical Vapour Infiltration
LMI	Liquid-Metal Infiltration
LAS	Lithium Aluminosilicate
CAS	Calcium Aluminosilicate
FRP	Fibre-Reinforced Polymer

KFRP	Kevlar-Fibre-Reinforced Plastics
FRC	Carbon-Fibre-Reinforced-Carbon Matrix Composites
Tg	Glass Transition Temperature
PVC	Polyvinyl Chloride
PAI	Polyamide-Imide
PEK	Polyether Ketone
LDPE	Low-Density Polyethylene
EVA	Ethylene Vinyl Acetate
PAC	Powdered Activated Carbon
GAC	Granular Activated Carbon
ACFs	Activated Carbon Fibres
DLC	Diamond-Like Carbon
PSAC	Palm Shell Activated Carbon
CoF	Coefficient Of Friction
UTM	Universal Testing Machine

LIST OF SYMBOLS

ρ	-	Density
SG	-	Specific Gravity
Vt	-	Total Volume
P	-	Porosity
Wt	-	Mass of wet sample (g)
Wo	-	Mass of dry sample (g)
Wabs	-	Water Absorption

CHAPTER 1

INTRODUCTION

1.0 Background

"Composite" can be defined as the combination of two or more different materials to form superior and unique material. Natural fibres reinforced materials have been used for more than 3,000 years, for example, reinforcing mud walls in houses with bamboo shoots, gluing laminated wood by Egyptians (1500 BC), and forging of swords by using laminated metals in (1800 ADs). Lately, in the 1930s, modern composites like glass fibres reinforced with resins, known as fibreglass, were used in built-out boats and aircraft, and in the 1970s, the composite industry has widely increased due to development of new fibres such as carbon, boron and aramid, and development of new composite systems with matrices made of metal and ceramics (Taj et al., 2007).

After that many researchers have developed composites using natural fibres such as bamboo, coir, sisal, and banana. They found that the mechanical properties of these composites will increase with the increase of the reinforcement content when the maximum values of (Young's modulus and the tensile strength around reinforcement content of 70 vol. %). The decrease in this percentage of the composite with the reinforcement content could be due to the insufficient filling of the matrix resin (Akil et al., 2011). The mechanical properties also depend on fibre's length, fibre orientation, weight ratio and interfacial adhesion between fibre and matrix. In the last two decades, there is an increased attention about polymer composites with natural organic fillers. Polymer matrix is biodegradable, comes from renewable sources and environment-friendly. Increasing global awareness about the environment and social concern, depletion of petroleum resources and new environmental regulations have prompted the scientific researchers to look for new alternatives to replace traditional polymer composites with ''Eco composites'' or ''green composites'' substitutes which have lower environmental impact, low cost, outweigh strength requirements, lightweight, non-toxic, non-abrasive and have low density. In general, Polymer materials have weak physical-mechanical properties compared with metals or ceramic materials. Therefore, polymer resins are reinforced by natural fillers (fibres, particles or powders) by plant sources such as activated carbon. The properties can be modified by using activated carbon particles to suit high strength/high modulus requirements (La Mantia and Morreale, 2011).

Each year, thousands of tons of different agricultural crops are produced in Malaysia, but most of these wastes do not have any useful utilization. These wastes can be used to produce fibre reinforced polymer composites for commercial use, especially in automotive and packaging materials, benefitting from agricultural waste by being renewable resources and have marketing appeal as another important economic resource. The production of palm kernel activated carbon (PKAC) with high porosity as reinforcement in polymer matrix to function as self-lubricated material has been tested by Chua et al. (2014), and it is available at affordable costs, but the attempts to find new raw materials to produce activated carbons are limited. Therefore, the use plant based sources such as palm kernel and other natural resources in Malaysia as carbon precursor will be very promising (Rahman et al., 2012).

1.1 Introduction

Twenty years ago, advanced materials were reflected by the length of development cycle. Nowadays, the demand for composite materials for various types of structures is increasing rapidly with significant major impact, such as in modern and advanced military aircraft. Composite materials are strong materials that consist of a combination of two or more substances of separate identities. Composite materials provide continuous quality in service, superior to the properties of individual materials (Hull and Clyne, 1996).

In recent years, almost any carbonaceous material can be converted into activated carbon, whether it occurs naturally such as coal and lignocellulose materials, or prepared synthetically such as organic polymers. One must tailor the activated carbon with high micro, mesopore volume and large specific surface area for application in specific use. The development of pores and their distribution mainly depends on the precursor type and the process of preparation. The resources of raw materials used for producing activated carbons are limited, thus the attempts to find new raw materials for this purpose are of great interest. The use of agricultural wastes in activated carbon industries would be favoured as it is economical and environmentally friendly. Huge amounts of palm kernel and coconut shells are produced as agricultural wastes in Malaysia. The utilization of these wastes as carbon precursor is very promising. Activated carbon as formaldehyde absorbent has been studied by various experts, for use as bio-scavenger for decreasing formaldehyde emission from melamine formaldehyde resin (Kim and Kim, 2006). The activated carbon acts by absorbing release formaldehyde from the wood panel (Darmawan, 2010) Today's advance technology can simulate test model in the design process for technical insight to reduce weight and material cost. At the same time, the durability and manufacture of the product can be evaluated. Furthermore, simulation can show the representation of the real model system in real time by computer. Simulation also enables visualization, and at the same time the editing of the model (Hubalovsky, 2013).

Large surface area, high degree of surface reactivity, universal adsorption effect and favourable pore size are some advantages of activated carbon as adsorbent (Gupta, 2009). Properties like surface area, pore volume and pore size distribution are linked with higher adsorptive capacities towards activated carbons. Activated carbons are also microporous. Micropores are categorized into meso and macropores, which are important in facilitating access of adsorbate molecules into the interior of carbon particles (Choi et al., 2009).

Studies have been conducted to reduce wear and friction by investigating different types of lubricants or coating materials for biological applications. Some researchers found that composites activated by either graphite or carbon have the potential to act as self-lubricating materials when reinforced with other metal materials, such as aluminium. Polymer composites possess a huge potential in substituting monolithic alloys due to their unique properties. Natural polymer composites are environmentally friendly as they are reinforced with natural elements such as corn fibre, kenaf powder, and palm ash compared to polymer composites which are reinforced with synthetic fibre such as glass and carbon fibres. Recently, a substantial amount of research has shifted focus from monolithic materials to composite materials to meet the global demand for lightweight, renewable, high-performance, eco-friendly, and wear and corrosion-resistant materials. The advantages of composite materials include their permeability (optimize waxing properties), cost effectiveness, and different strengthening mechanisms. This current study investigates the PKAC-E composite with different ratios of physical-mechanical properties to determine optimum parameter's values (heat, pressure, compressing time) when preparing the samples.

1.2 Problem Statement

Palm kernel activated carbon-epoxy (PKAC-E) composite is a novel composite which has good tribological properties with high resistance to friction and wears rate at different temperatures and loads. However, no previous studies in the literature have focused on the physical-mechanical properties of (PKAC) as reinforcement in polymer matrix materials. The absence of physical-mechanical properties reduces the chances of use in other applications, thus it is necessary to study the influence of reinforcement content on physical-mechanical properties to suit high strength/high modulus requirements, with a probability of employment in other diverse applications.

1.3 Research Objectives

The research objectives in this study are as follows:

1. To determine optimum process parameters, which are temperature, pressure and compression time of preparing a PKAC-E composite for hardness property.
2. To investigate the effect of PKAC-E composition on the physical-mechanical properties of the composite based on the optimization value.
3. To compare the physical-mechanical properties of PKAC-E composite with other synthetic-natural reinforced composite materials.

1.4 Scope of the Study

In this study, PKAC-E composites were subjected to a number of physical-mechanical (tensile and hardness) tests in addition to performing density, porosity, and water absorption tests to determine the influence of reinforcement content on the physical-mechanical properties. Hardness and density tests were conducted for comparison purposes with other synthetic and natural based polymer composites respectively, to further investigate the potential of PKAC-E composite in industrial and machinery applications.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The fusion (blend) of two or more materials with different mechanical, chemical or physical properties produce composite materials.

Carbon-Carbon (C-C) composites combine two major elements, which are carbon matrix and carbon fibres. These composites are then significantly improved for many applications and preferred over other materials because they have consistent stability and structural at high temperature due to light weight, strong stiffness, toughness, superior thermal coefficients, ablation, and high-speed friction properties. The components of Carbon-Carbon (C-C) composites have been manufactured in the United States in the last three decades for most aerospace and defence applications. Carbon-carbon composites are the best option due to weight ratios and excellent refractory properties for severe and tough environmental applications, for instance, in rocket motor exhaust, and in the high-performance military or commercial aircraft, racing cars and high-speed trains as disk brakes.

To ensure efficient engineering development process, standardised and statistically-based material properties are required by material suppliers, engineers, and system end-users. Since the inherent properties of materials are independent of specific applications, data development methodologies and material property data are applicable to a wide variety of industries; they also form much of the technical basis for the establishment of statistically-based design values acceptable to procuring or certifying agencies. Several researchers have found that composites activated by either graphite or carbon have the potential to act as self-lubricating materials wherein forced with other metal materials, such as aluminium (Bakry et al., 2013, Zamri and Shamsul, 2011 & Yusoff et al., 2010).

Activated charcoal is a form of processed carbon, which is highly porous and has a wide surface area that enables chemical reactions and absorptions. Activated carbon is commonly derived from charcoal. As typically determined by nitrogen gas absorption, 1 gram of activated carbon covers an area about one-tenth the size of an American football field (Pradhan, 2011). This factor enables sufficient activation for useful applications which may come solely from the high surface area although further chemical treatment can enhance the absorbing properties of the materials.

Many investigations and studies in the literature have focused on reinforcing the polymer composites in natural fillers (Akil et al., 2011, Maleque et al., 2007, Taj et al., 2007 & Sapuan et al., 2003). Fibre and matrices are the two main components of composite materials. Fibres function as a reinforcement to support the high-density load whereas the matrix imparts rigidity to the composite through the bonding of reinforcing fibres together and to transfer the applied stresses from the composite to the fibres. This work mainly addresses evaluation of some physical-mechanical properties to PKAC-E composite and their effects on its performance. The literature review presents brief descriptions of some previous works.

2.1 Composite Materials

Generally, two or more materials are combined to form a composite material with unique properties. However, they can be distinguished separately within the finished blend as they do not fuse into each other. Composite materials are stronger, lighter, or less expensive compared to traditional materials. More recently, researchers have also begun to actively include sensing, actuation, computation and communication into composites (McEvoy & Correll, 2015), which are known as Robotic Materials.

Typical engineered composite materials include:

- Composite building materials, such as cement and concrete
- Reinforced plastics, such as fibre-reinforced polymer
- Metal composites
- Ceramic composites (composite ceramic and metal matrices)

Composite materials are generally used for buildings, bridges and structures, such as boat hulls, swimming pool panels, race car bodies, shower stalls, bathtubs, storage tanks, imitation granite and cultured marble sinks and countertops. The most advanced examples are applied in the construction of spacecraft and aircrafts for use in demanding environments.

2.1.1 History of Composite Material

Appropriate fusion of matrix and reinforcement material can produce light and strong composites to meet the expectations of new application. Furthermore, flexible composites can be molded into complex shapes. However, some composites may not be cost effective since their raw materials are already costly. The Egyptian documented ancient brick manufacturing by a combination of straw and mud for building constructions. According to Shaffer (2013), daub and wattle are also one of the oldest man-made composites nearly 6000 years ago. Concrete is a composite that has been used for a long time compared to any other materials.