UNIVERSITI PUTRA MALAYSIA

MECHANICAL AND BALLISTIC PROPERTIES OF COIR COMPOSITE PANEL

NURAISHAH BAZILAH BINTI AFFANDI

MECHANICAL AND BALLISTIC PROPERTIES OF COIR COMPOSITE PANEL

By

NURAISHAH BAZILAH BINTI AFFANDI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

November 2012

In the name of Allah, Most Gracious, Most Merciful

This thesis is dedicated to:

Husband, Muhammad Nizam bin Omar

Affandi bin Hussien & Family

Omar bin Ahmad & Family

Family & Friends

...

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chair: Azmin Shakrine bin Mohd. Rafie, PhD

Faculty: Engineering

The focus of the study about randomly-woven coir sheets is to determine its potential as a kinetic energy absorber with the aim of implementing the sheet as an impact-worthy constituent. Among the effects of this study are the extension in the service life of raw coir, nomination of coir sheet as a competitive alternative to conventional materials and contribution towards the knowledge of coir in the continuous form as other studies tend to focus on coir in the discontinuous form. Tensile tests using a universal testing machine to determine the mechanical properties and ballistic impact tests using a light-gas gun and high-speed camera to determine the energy absorption properties were performed on fabricated specimens. The coir/epoxy composite specimen consisted of coir sheets layered together with epoxy resin minimally applied to adjacent exterior sheet surfaces, thus leaving the core of the sheet practically partially hollow, where the weight of the sheets and thickness of the resin were controlled. Through this work, a 1-layer of this composite behaves in a brittle fashion and has a modulus and tensile strength of 93.85 MPa and 2.77 MPa, respectively. The 2-layer and 3-layer

behaves in a ductile fashion and has a modulus and tensile strength of 46.99 MPa and 1.77 MPa, and 40.07 MPa and 2.70 MPa, respectively. The relation between the number of layers and absorbed kinetic energy has too been discovered for this particular composite to be $f(x) = 12.62x - 0.02$. To totally stop a projectile moving at 205 m/s, it has been found that a 10-layer composite (with a dimension of 100 mm (L) $\times$ 100 mm (W) $\times$ 8 mm (T) and weighing 12 g per sheet) of this fiber is needed.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

SIFAT MEKANIKAL DAN BALISTIK BAGI PANEL SABUT KELAPA KOMPOSIT

Oleh

NURAISHAH BAZILAH BINTI AFFANDI

November 2012

Pengerusi: Azmin Shakrine bin Mohd. Rafie, PhD

Fakulti: Kejuruteraan

Penyelidikan mengenai sabut kelapa tenun-rawak ini adalah untuk menentukan potensinya sebagai penyerap tenaga kinetik dengan tujuan untuk menjadikan lembaran serat sebagai juzuk hentaman-wajar. Antara kesan dari kajian adalah memanjangkan tempoh guna sabut, menjadikan sabut kelapa sebagai alternatif yang berdaya saing kepada bahan-bahan konvensional dan seterusnya menyumbang kepada pengetahuan tentang sabut sebagai serat selanjar kerana kajian-kajian lain cenderung memberi tumpuan kepada sabut sebagai serat tak selanjar. Ujian tegangan menggunakan mesin ujian semesta untuk menentukan sifat mekanik dan ujian hentaman balistik menggunakan penembak gas ringan dan kamera pantas untuk menentukan sifat penyerapan tenaga telah dijalankan ke atas spesimen terbikin. Spesimen komposit sabut/epoksi disediakan daripada kepingan sabut dilapis-lapiskan dengan resin epoksi yang diletakkan sedikit sahaja di permukaan luar kepingan yang bersempadanan, dengan itu sekaligus meninggalkan teras kepingan separa kosong secara pratikal, di mana berat kepingan dan ketebalan resin dikawal. Melalui kerja ini, 1-lapis komposit ini berke-

lakuan rapuh dan mempunyai modulus dan kekuatan tegangan, masing-masing ialah 93.85 MPa dan 2.77 MPa. Manakala komposit 2-lapis dan 3-lapis berkelakuan mulur dan masing-masing mempunyai kekuatan modulus dan tegangan 46.99 MPa dan 1.77 MPa, dan 40.07 MPa dan 2.70 MPa. Hubungan antara bilangan lapisan dan tenaga kinetik terserap telah dijumpai untuk komposit khusus ini iaitu $f(x) = 12.62x - 0.02$. Untuk menghentikan sepenuhnya sesuatu peluncur yang bergerak pada 205 m/s, telah ditemui bahawa 10-lapis komposit (dengan dimensi 100 mm (P) $\times$ 100 mm (L) $\times$ 8 mm (T) dan seberat 12 g per lembaran) daripada serat ini diperlukan.

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(4) Master of the Day of Judgment.

(5) Thee do we worship, and Thine aid we seek.

(6) Show us the straight way,

(7) The way of those on whom Thou hast bestowed Thy Grace,
those whose (portion) is not wrath, and who go not astray.

Thank you, Allah, for everything.

My humble apology and heartfelt gratitude to all involved with the ups and downs of this study. The cover of this thesis does bear a single name that of which declares me as the author of this work. Under the cover, this thesis symbolizes the collected work of a team.

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I certify that a Thesis Examination Committee has met on 9 November 2012 to conduct the final examination of Nuraishah Bazilah binti Affandi on her thesis entitled "Mechanical and Ballistic Properties of Coir Composite Panel" in accordance with the Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Harijono Djojodihardjo, PhD, Ir
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Faizal bin Mustapha, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Rizal bin Zahari, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Roslan Ahmad, PhD
Associate Professor
School of Mechanical Engineering
Universiti Sains Malaysia
Malaysia
(External Examiner)

SEOW HENG FONG, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Azmin Shakrine bin Mohd. Rafie, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairperson)

Renuganth Varatharajoo, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

NURAISHAH BAZILAH BINTI AFFANDI

Date: 9 November 2012

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LIST OF ABBREVIATIONS

C	calibration
D_x	horizontal distance
D_y	vertical distance
F_f	final frame
F_i	initial frame
F_r	frame rate
fps	frames per second (unit)
m_p	mass of projectile
px	pixels (unit)
V_p	velocity of projectile

CHAPTER 1

INTRODUCTION

1.1 Thesis statement

Diverse studies focusing on natural fibers are being carried out world-wide to evaluate the properties and potential of these fibers under various applications. At the same time, the studies attempt to exploit and integrate the fibers into fields dominated by costly materials or simply create a new entity. The study by Wambua et al. [1], for instance, compares the response of flax, hemp, and jute; at the same time combines the discipline of natural fiber, composite and armory. Where possible, these environmentally friendly fibers are deemed to be cheaper and light-weight yet competitive alternatives. Of the commercial natural fibers, namely flax, hemp, jute, ramie, coir, sisal, abaca and cotton [2], coir has the lowest density (1.25 g/cm^3) whilst the highest is cotton (1.51 g/cm^3). The tensile strength (220 MPa) and elastic modulus (6 GPa) of coir, although being the lowest, are countered by the fibers' elongation rate at failure (15-25%) which is the highest.

Some of that focus needs to be diverted to coir in order to identify and develop the fiber's potential, especially when there exist intentions to absorb it into aerospace applications, e.g., a coir composite wing or fuselage. Before suggesting an application the natural fiber needs to be proven to have potential first before it is either accepted or rejected. This challenge will most probably attract the attention of those who invest interest in the material development of the aerospace industry investigate the impact behavior and properties as it creates a window of possibility in cost control of materials; and those involved in the terminal ballistics discipline. Making use of coir in such a way may dawn upon some as a weird endeavor, particularly at this time and age. History, however, has recorded otherwise; for example, Prophet Noah's majestic ark was caulked with palm fiber [3].

1.2 Problem statement

The potential of coir along with many other natural fibers have been given attention in numerous studies in various ways. Even throughout time itself man has made use of natural fibers in many ways. Attempt to integrate coir with other recognized aerospace material furthermore with an aerospace application has yet to be undertaken. This study intends to investigate potential of coir sheet as a kinetic energy absorber with a future vision to implement the composite in the fuselage of a light aircraft. The debris impact on the underbelly of the fuselage involves the terminal ballistic discipline to simulate the debris impact [4].

Once the potential of the coir composite is established it can be incorporated with other conventional engineering materials (e.g., aluminum, steel). Capabilities of composites and conventional engineering materials are at their utmost performance when utilized jointly [4], and the sandwich structure is an example of joint use. A high performance sandwich structure composite consists of fiber-reinforced plastic skins and a low-density core [5]. The potential of coir sheets as a kinetic energy absorbent, however, is a novel study. As it is a novel study, the foundation has to be laid for others to build upon. The question is: "Is it possible?"

1.3 Significance of the study

From root to fruit, studies based on coconuts have been done where coir is the main focus if not a subordinate of the study. Revealing the behavior of coir in its continuous form is the significance of this study in contributing towards that pool of knowledge.

1.4 Objectives of the study

The objectives of this study are:

1. To establish a method of fabricating coconut fiber (coir) sheet composites.
2. To attain the mechanical properties of the coir composite.
3. To measure and compute the energy absorbed by the coir composite by conducting ballistic impact tests using an 8.5 mm in diameter, blunt-nosed, mild steel projectile.

1.5 Expected outcome

The end products expected by the end of this study are: the fabrication method of coir composite, the mechanical properties of the coir composite specific to the fabrication method, and the estimation of the absorbed kinetic energy for the coir composite.

1.6 Limitations of the study

This study focuses on the ability of coir composite to absorb translational kinetic energy, subsequently its potential as the core of an ideal composite. The subject matter is coir sheets with random fiber orientation measuring 100 mm (L) $\times$ 100 mm (W) $\times$ 8 mm (T) and weighing $12^{+0.4}_{-0.5}$ g throughout this study. The dimension of 100 mm (L) $\times$ 100 mm (W) comes from a previous study by Hameed Sultan [6] who used fiberglass instead.

Ballistic impact tests in this study are limited to normal impact. Blunt-nosed projectiles are selected over round- and sharp-nosed projectiles. Throughout the impact testing, two square-shaped rigid steel frames each with a circular aperture holds the specimen. The effect of the frame size and type upon the residual speed and the residual kinetic energy of the projectile are neglected, as well as the effect of the clamping pressure [7]. Shock waves generated by the impact of the projectile onto the specimens [8] are also neglected.

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