WOVEN KENAF BAST FIBRE AS AN ALTERNATIVE FOR GLASS FIBRE STOCKINETTE IN LAMINATED COMPOSITE STRUCTURE TO FABRICATE PROSTHETIC LEG SOCKET

ROSALAM BIN CHE ME

IPTPH 2012 6

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By

ROSALAM BIN CHE ME

Thesis Submitted to the School of Graduates Studies Universiti Putra Malaysia, in Fulfillment of the Requirement for the degree of Master of Science

November 2012

DEDICATIONS

To my beloved parents, Che Me Bin Awang Cha and Che Sam Binti Omar

My beloved brothers and sisters

My loving friends

Thanks for your patience, encouragement and loving support.

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

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Chairman : Professor Rahinah Ibrahim, PhD

Institute : Institute of Tropical Forestry and Forest Product

Artificial limbs may be needed for a variety of reasons including disease, accidents, and congenital defects. As people's bodies change over time, due to growth or change in body weight, the artificial limbs have to be changed periodically or adjusted by time. This constant need to change becomes costly if the material used is expensive. This study emphasized on the sockets part as of prosthetic leg as they are require replacement due to wear and tear, as well as to maintain the comfort of wearers. Presently, socket of prosthetic leg is made of Glass Fibre Reinforced Plastic (GRFP).

In this study, woven kenaf fibre is used in one or two layers of the laminated composite as a replacement for glass fibres. The study hypothesized that woven kenaf fibre mat can

be reinforced in the existing laminated composite structure to replace or as an alternative for glass fibre stockinette to fabricate socket of prosthetic leg.

Basically, the current research aimed to prepare the laminated woven kenaf composites to compare with the existing lamination structure (or control) in terms of their mechanical (tensile, flexural and impact) and physical (density and moisture content) properties in identifying both strengths and weaknesses. A true experiment designwas adopted to quantify, if there is any significant difference between four variables which consist of the control and three proposed kenaf laminated composites. These composites were prepared using sandwich layering or lamination technique, adopting a similar technique used to fabricate sockets of prosthetic legs.

Results of the study suggest that the incorporation of kenaf in the existing composite structure has resulted in the positive improvement in the mechanical and physical properties. The incorporation of one layer of woven kenaf bast fibre (composite 2) has proven that this particular composite is best in tensile and tensile Young's Modulus and in flexural strength. Whereas, inclusion of two layers of woven kenaf bast fibre (composite 3) has resulted in giving the highest value of Izod impact strength, flexural Young's modulus and density.

Further analysis discovered that there is no significant difference between these two composites. Therefore, this finding suggests that the best proposed material (laminated woven kenaf fibre composite) to be used as an alternative material for the existing (glass-fibre) laminated composite to make socket of prosthetic leg is composite 3 which contains two layers of woven kenaf bast fibre. Although this composite does not contain glass fibre, it has compatible qualities to fabricate socket which resulting in providing alternative material which is more cost efficient and considered as ‘Green’.

A prototype of prosthetic leg integrated with socket which is made of the best proposed laminated composites (composite 3) was made to verify the success of this finding throughout this study.Additionally, this prototype also proved that woven kenaf laminated composite is able to be produced commercially to save the total cost of manufacturing the prosthetic leg since kenaf fibre is cheaper as compared to glass fibre.

Abstrak tesis yang diekemukakan kepada Senat Universiti Putara Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

ANYAMAN SERAT KULIT KENAF SEBAGAI ALTERNATIF KEPADA SARUNG GENTIAN KACA DI DALAM STRUKTUR LAMINASI KOMPOSIT UNTUK MENGHASILKAN SOKET KAKI PALSU

Oleh

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Anggota badan palsu diperlukan atas banyak kemungkinan termasuklah disebabkan penyakit, kemalangan and kecacatan sejak lahir. Oleh kerana badan manusia berubah mengikut peredaran masa, sama ada disebabkan pertumbuhan badan atau perubahan dari segi berat badan, anggota badan palsu perlu ditukar atau dibaiki secara berkala. Faktor yang membawa kepada keperluan ini akan menjadi bebanan kepada pengguna sekiranya bahan yang digunakan mahal. Kajian ini akan memfokuskan tentang bahagian soket, kerana ia kerap ditukar dan ia juga menentukan keselesaan pemakainya. Lazimnya, soket kaki palsu diperbuat daripada gentian kaca yang diperkuatkan oleh plastik (GFRP).

Dalam kajian ini, satu atau dua lapisan anyaman serat kenaf dimasukkan ke dalam laminasi komposit sebagai ganti kepada gentian kaca. Hipotesis kajian ini adalah anyaman serat kenaf boleh dimasukkan ke dalam struktur laminasi komposit asal bagi menggantikan atau sebagai alternatif kepada sarung gentian kaca untuk menghasilkan soket kaki palsu.

Secara asasnya, kajian ini bertujuan bagi menyediakan komposit laminasi dari anyaman kenaf untuk dibezakan dengan struktur laminasi asal atau komposit kawalan dari aspek mekanikal (regangan, lenturan dan hentakan) dan fizikal (ketumpatan dan tahap kelembapan) bagi mengetahui kekuatan dan kelemahannya. Satu eksperimen dijalankan bagi menentukan jika terdapat perbezaan ketara di antara empat variabel iaitu komposit asal dan tiga cadangan komposit laminasi. Semua komposit ini telah disediakan menggunakan teknik apitan beberapa lapisan bahan, adaptasi dari salah satu teknik untuk membuat soket kaki palsu.

Keputusan dari kajian ini mencadangkan bahawa kemasukan kenaf ke dalam struktur komposit asal telah menunjukkan peningkatan positif dari aspek mekanikal dan fizikal. Kemasukan satu lapisan anyaman dari kulit kenaf (komposit 2) telah membuktikan bahawa komposit ini adalah yang paling paling baik dari segi kekuatan regangan dan modulus dan kekuatan lenturan. Sebaliknya, kemasukan dua lapisan anyaman dari kulit kenaf (komposit 3) telah menunjukkan nilai tertinggi dalam kekuatan hentakan Izod, regangan modulus dan ketumpatan.

Analisa lanjut telah membuktikan bahawa tiada perbezaan ketara di antara kedua-dua komposit ini. Oleh itu, dapatan kajian ini mencadangkan bahawa bahan cadangan terbaik (komposit dari anyaman kulit kenaf) untuk digunakan sebagai bahan alternatif kepada komposit laminasi asal untuk membuat kaki palsu adalah komposit 3 yang mengandungi dua lapisan anyaman kenaf. Ini kerana komposit ini tidak megandungi sebarang gentian kaca tetapi menyediakan kualiti yang setanding dengan bahan asal dan pada masa yang sama boleh digunakan sebagai bahan alternatif yang lebih berpatutan harganya dan lebih mesra alam.

Sebuah prototaip kaki palsu yang menampilkan soket yang diperbuat daripada bahan cadangan terbaik (komposit 3) telah dihasilkan bagi membuktikan kejayaan hasil kajian ini. Prototaip ini juga menunjukkan bahawa komposit laminasi dari anyaman kenaf boleh dihasilkan secara komersial untuk menjimatkan kos pembuatan kerana serat kenaf lebih murah jika dibandingkan dengan gentian kaca.

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Finally, my deepest gratitude goes to my beloved family, colleagues and friends for their support and patience throughout this process. Their patience and sacrifice during this entire process may never be completely appreciated.

I certify that a Thesis Examination Committee has met on 12th November 2012 to conduct the final examination of Rosalam Bin Che Me on his Master of Science thesis entitled "**Woven Kenaf Bast Fibre As an Alternative for Glass Fibre Stockinette in Laminated Composite Structure to Fabricate Prosthetic Leg Socket"** in accordance with the Universities and University Colleges 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 Master of Science.

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DECLARATION

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

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ROSALAM BIN CHE ME

Date: 12th November 2012

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LIST OF ABBREVIATIONS

A	Area
AK	Above Knee
ANOVA	One-Way Analysis Of Variance
ASTM	American Society for Testing and Materials
BK	Below Knee
CAD/CAM	Computer-Aided Design and Manufacturing
DAP	Day After Planted
DP	Degree of Polymerization
FRP	Fiber Reinforced Plastic
GPa	Giga Pascal
GRFP	Glass Fibre Reinforced Plastic
ISO	International Organization for Standardization
J	Joule
Kg	Kilogram
LSD	Least Significant Difference
MC	Moisture Content
MOE	Modulus of Elasticity
MOR	Modulus of Rapture
MPa	Mega Pascal
N	Newton
NA	Not Available
NF	Natural Fibre
PALF	Pineapple Leaf
POP	Plaster of Paris
PP	Polypropylene

PVA	Polyvinyl Alcohol
PVC	Polyvinyl Chloride
RM	Ringgit Malaysia
RQ	Research Question

CHAPTER 1

INTRODUCTION

1.1 Introduction

This first chapter offers the general introduction of this study, which is the utilization of natural fibre as a reinforcement matrix in composite to be applied in prosthesis manufacturing. It then elaborates on the causes and needs of the lower limb prosthesis. This subtopic discusses what could cause limb loss, numbers of amputation cases and the needs of providing the more cost-efficient prosthesis, alternatively made from natural-based material. Subsequently, this chapter will discuss further on the prosthesis with lower manufacturing cost, responding to the earlier subtopic. The lower manufacturing cost of prosthesis will not only thrive in providing the alternative way of producing prostheses, but also maintain the qualities of the prosthesis itself.

Subsequently, this chapter states the research questions and research objectives. It summarizes the problem statement and the chosen experimental research method. Finally, the whole chapter is briefly explained in the chapter overview. This thesis has five chapters: the first chapter is the introduction, second chapter literature review, third chapter materials and methods, fourth chapter results and discussions and the fifth chapter is conclusion and recommendations.

1.2 Background of the Problem

Artificial limb or prosthesis is meant to replace the missing limb and it is designed to substitute or imitate the function or appearance of it as agreed by Arvela et al. (2010). In order to create a successful prosthesis, the designer and manufacturer have to understand how the limb functions. This is to ensure that the prosthesis can actually replace the missing limb and can be significantly helpful to the wearers. However, before any prosthesis is produced, many aspects must be taken into account and material is among one of the most important aspects. Material selection, for instance, plays an important role in prosthetic manufacturing because it determines the comfort, durability and flexibility of the prosthesis.

Nowadays, more advanced materials have been used to replace the conventional material because advanced materials have more advantages (Myrdal, 2009). As been mentioned in his study, in the lower limb prosthetic manufacturing for instance, conventional material such as leather, wood, latex and metal have been replaced with thermoplastic, composites and other synthetic materials.

This study is aimed at discovering a better solution by providing an alternative material to make the most important part of a prosthetic leg, which is the socket. One of the techniques to fabricate socket is called lamination. This technique requires the lamination of different material layers in order to form the laminated socket and one of the materials which give the most strength towards the end product is glass fibre stockinette (woven glass fibre). Many research findings have proven the importance of using glass fibre in many applications due to its benefits as stated by Brown, Davis, Jonnalagadda and Sottos (2004) and Hartman, Greenwood, and Miller (1996). However, a good synthetic fibre like this also has its drawbacks, and some of the drawbacks could harm the environment and the person who works with it (Wambua, Ivens, & Verpoest, 2003). This is the reason many researchers from all over the world try to develop a better alternative for this synthetic material and most importantly it should come from renewable sources because of its low environmental impact. One possible alternative material is natural fibre.

Natural fibre reinforced composite has been used widely for decades. The properties of natural fibre itself have long attracted many manufacturers. Natural fibres like jute, pineapple leaf, sisal flax, hemp, kenaf, coir and abaca have been used by researchers to replace inorganic fibres (glass, aramid and carbon) in reinforced composites (Wambua et al., 2003).The use of natural fibres has many advantages such as low density, abundant availability, low cost and good mechanical properties. In addition, natural fibres are used in various applications for their relative cheapness as compared to conventional materials and synthetic fibres such as glass and aramid fibres, their recyclability, and for the fact they compete well in terms of strength per weight material as suggested by Robson, Hague, Newman, Jeronomidi, and Ansell (1996).

For the purpose of this study, the researchers proposed the combination of natural fiber with the existing material to fabricate prosthetic leg sockets. This combination was put forward based on the related studies found in the review of literature (Chapter 2). For instance, Joshi, Drzal, Mohanty, and Arora (2004) in their report propose that natural-fiber (such as kenaf, flax, hemp and so forth) can be reinforced with polymer to be used in many other applications including automotive part manufacturing, due to the lower manufacturing cost and lower density. Therefore, the use of natural fiber as one of the layers in the prosthetic socket lamination could reduce the manufacturing cost by lowering raw material cost and at the same time providing an eco-friendly alternative to plastic-based materials.

Hypothetically, if the proposed kenaf fiber based biocomposite has the same qualities with the existing material, it can be used to make artificial limbs (especially socket of prosthetic legs). Therefore, the thesis is proposing a new material structure (by imitating the existing material structure) which could probably be more cost efficient and give better or similar mechanical properties as compared to existing materials. The alternative material (which is based on natural fibre) offers additional advantages including being biodegradable, recyclable and renewable, as recommended by Robinson et al. (1993). At the same time, the thesis expects to benefit those who cannot afford to have this artificial limb due to the high market price.

1.3 The Causes and Needs of Lower Limb Prosthesis

Limb loss affects a variety of people in the United States and around the world and includes people of every race, ethnicity and background without regard to geographic locations, occupations or economic levels (Ide, 2010). In developed countries, the main cause of lower limb amputation is circulatory dysfunction. According to Dromerick et al. (2008), the prime reason for this is arthrosclerosis, although up to a third of patients have concomitant diabetes. These people are usually in their 6th decade or older and most have additional health problems that limit their working ability.

In the United Kingdom, there are about 5000 major new amputation cases each year. This is in sharp contrast with other developing countries where most amputations are caused by trauma related to conflict or to industrial or traffic injuries (Arya & Klenerman, 2008). From a study conducted by Fergason, Keeling, and Bluman (2010), global extrapolations are problematic but the recent US study states that the amputation rate among combatants in the recent US military conflict remains at 14-19% and the devastation caused by land mines continues; particularly, when displaced civilians return to mine areas and resume agricultural activities.

The National Limb Loss Information Center (2010) for instance, reported that the main cause of acquired limb loss is poor circulation in a limb due to arterial disease, with more than half of all amputations occurring among people with diabetes mellitus. Limb amputation may also occur after a traumatic event or for the treatment of a bone cancer. In contrast, a congenital limb difference is due partly to the complete or partial absence of a limb at birth.Johannesson et al. (2010) stated that the risk of limb loss increases with age; those aged 65 years or older have the greatest risk of amputation. As with diabetes and heart disease, smoking, lack of exercise and poor nutrition may also increase the risk of limb loss (Johannesson et al., 2010). Here, it implies that the older people are, the higher their chance of facing limb loss.

The causes of limb loss vary from one region to another. At present, the cost of producing prosthetic legs is expensive. An alternative way to produce cheaper prosthetic legs is needed to ensure that low-income wearers get to enjoy cheap and comfortable prosthetic legs. Thus, in this case, cutting down the cost of manufacturing by offering a cheaper material will be one of the solutions.

1.4 Low Manufacturing Cost of Prosthesis

The goal for most of the new prosthetic designs is to duplicate the motion of natural limbs as closely as possible for some expected ambulation (Liu, William, Liu, & Chien, 2010). However, the problem at present with the prosthetic and orthotic productions is costly design and development phases using expensive software applications although some CAD/CAM applications can precisely model near exact ambulation; still, the cost of manufacturing is high (Bové, 2010). The study agrees with both Arya and Klenerman (2008) and Jensen and Raab (2006) who believed that with minimal use of software applications and with less-costly technology used to design and produce prosthetic and orthotic products, many low-socio-economic users will benefit from this research area.

Presently, as affirmed by Marks and Micheal (2001), the contemporary industrial fabrications, for instance, principally with the injection molded plastic technique can create lightweight and low-cost components with satisfactory function for limited walking, and this might be quite adequate for today's typical elderly amputees and without the assistance of expensive software applications. This is especially true for those amputees who live in economically less fortunate countries such as in the developing or Third World. Third World countries' amputees who are less financially able to afford expensive prosthetic devices will seek cheaper but cosmetically-attractive prosthesis (Meanley, 1995).

In Malaysia, the numbers of Type-2 diabetic amputees are increasing exponentially each year as reported by the National Diabetes Institute (2010). In their article, Ooi, Abu Saman, and Wan Abas (2010) reported that in the Malaysian Context, Department of Social Welfare Malaysia (JKKM) registered about 58, 371 amputees in 2005, 66250 in 2006 and 73,559 amputees in 2007. This increasing number of amputees reveals the need to have low-priced prosthetic devices. Therefore, cost-efficient prosthetic parts and components and devices which are produced using inexpensive technology are much needed and sought after (Sewell, Noroozi, Vinney, Amali, & Andrews, 2010).

Jensen and Raab (2006) and also McFarland, Winkler, Heinemann, Jones, and Esquenazi (2010) argued that with restricted financial resources offered by many governments around the world to help low income amputees, prosthetic components and devices ought to reach more amputees and less expensive cost of production for these components and devices should be proposed. However, in Malaysia this is not the case for many components are still imported especially in terms of design or the ready built prosthetic devices. Hopefully, the study proposes to fill this gap with alternative ways to produce much cheaper prosthetic devices.

Nevertheless, regardless of geographical areas, production costs are still high and moreover if prostheses are imported, the price may be even higher (Jensen & Raab, 2006). For instance, Strait (2006) reported that a typical prosthetic limb made in a developing country costs between USD 125 to USD 1875 each.

Since prosthetic and orthotic productions are often based on imported components, especially in developing countries (such as ready-made feet and knee joints for prostheses), the locally made invention of prosthetic and orthotic products will save the flow of foreign exchange out of the country. As agreed by Eklund (1995), imported prosthetic and orthotic products are used in high quality orthopedic appliances but because of the high cost of production at present, only a limited number of people will benefit from these exclusive prosthetic and orthotic products. If a less sophisticated technology without compromising compromise is used, many more low income amputees can be fitted with the advent of low cost but cosmetically-attractive prosthesis.

The argument by many opponents would be that the advent of this low cost but cosmetically-attractive prototype will still be expensive in terms of the production cost. However, the logic here is that if less imported raw materials are used in producing prosthetic and orthotic products, it would reduce the manufacturing cost (Jensen & Raab, 2006; McFarland et al., 2010). In sum, the low cost and high quality prosthetic parts and components are highly sought after by many prosthetic and orthotic producers. If this is the case, then one possible solution is to propose inexpensive parts and components to reduce production cost.

1.5 Manufacturing Cost Reduction of Lower Limb Prostheses

During the preliminary interviews conducted among prosthetic manufacturers in Klang Valley who produced or imported prosthetic legs they admitted that the production cost varied from each type of prostheses to be produced. For Tans-tibial or Below Knee (BK) prosthetic leg for instance, it could cost from RM 4,000 to RM 12,000 each, while for one complete set of Transfemoral or Above knee (AK), the price started from RM 7,000 to RM 20,000.The price includes all the manufacturing costs involved in the production like materials used, components, and workmanship. Revealing the price of manufacturing is always a trade secret and they were hesitant to truthfully reveal the cost of the product.

Blough et al. (2010) in their study conducted a survey to focus group participants to estimate the cost of typical prosthetic device systems. From the survey, they discovered that this cost depended basically on three characteristics: the type of prosthetic device (by varying degrees of technology), the level of limb loss, and the functional capability. Hence, a simple but well-functioning prosthetic device with minimal software applications, low-cost technology, less imported parts and cheaper materials could lessen the overall cost and at the same time reduce the selling price of prosthesis devices.

As stated previously, it is difficult to figure out the actual operating cost to produce one prosthetic leg because this cost projection is a trade secret for each manufacturer. Nevertheless, an estimation of the manufacturing cost can be performed based on several aspects which are the types of prosthesis, fabrication techniques, and material selections, integration of devices and components and also the cost of labor.

Further description of prosthetic leg is discussed in Chapter 2, but basically, there are three main parts in one prosthetic leg (for both AK and BK) which are socket, pylon/tube and foot (Facoetti, Gabbiadini, Colombo and Rizzi, 2010). This study is emphasized on the socket part (as discussed in Chapter 2) due to the potential consumption of this part to be fabricated using a more cost-saving alternative material which is based on natural fibre, kenaf specifically. Highsmith, Carey, Koelsch, Lusk, and Maitland (2009) suggested that, at least 20% of the total cost of the prosthetic leg was dependable upon the socket, excluding the workmanship of the prosthetic leg. The cost to fabricate socket can be reduced by cutting down the cost of material.

In one of the socket fabrication techniques called lamination, the conventional material used is glass fibre. Recent related literature review on this has proven that kenaf fibre has the comparable properties (mechanically, and physically) to replace the glass fibre in socket fabrication using the lamination technique. National Kenaf and Tobacco Board

(LKTN), 2011 has revealed the market price of kenaf in Malaysia which ranges from RM 0.50 to RM 3.3 per kg, depending on the fibre types. This price is apparently almost five times lower than the price of glass fibre in global market, which is approximately RM 6.14 to RM 9.98 per kg. The price differences between these two fibres will benefit greatly to the cost of socket production which at the end resulted to the reduction of total manufacturing cost of one prosthetic leg.

1.6 Research Objectives

The general aim of the study is to develop composite made of Tubular kenaf woven to fabricate prosthetic leg socket. The mechanical and physical properties of this composite were studied. The main objectives of this study are:

1) To evaluate and identify the most suitable lamination method to produce prosthetic leg socket made of kenaf fibre-based bio-composite;
2) To identify the preparation of controland proposed material composite incorporated with woven kenaf fibres;
3) To compare the mechanical and physical properties of and controlproposed laminated composites; and also
4) To develop the most suitable material to replace or as an alternative of glass fibre stockinette in making socket of prosthetic leg.

1.7 Research Questions

As preceded above, the need for a more cost efficient and environmental friendly prosthetic is highly demanded based on the facts that the numbers of amputees are constantly subsisted due the possible causes as discussed earlier. Kenaf is one of the potential natural fibres to be reinforced with the existing laminated composite based on its properties that is environmentally superior to glass fibre (Joshi, Drzal, Mohanty, & Arora, 2004). Proposing the laminated composites made of this kenaf natural fibre could accomplish the main goal of this study which is providing an alternatively cost-efficient material to make socket of prosthetic leg. Therefore, the main research question of this study is:

Main RQ: What is the best proposed laminated composite structure (incorporation of woven kenaf fibre) to replace the existing laminated composite for prosthetic leg socket fabrication?

Sub RQ1: What is the most suitable lamination method to produce inexpensive prosthetic leg socket made of kenaf fibre-based bicomposite?

Sub RQ2: How to incorporate kenaf into the existing laminated composite structure in order to prepare the proposed laminated composites?

Sub RQ3: What are the mechanical and physical properties of control and proposed laminated composites?

Sub RQ4: Which proposed laminated composite is best to replace or as an alternative for the existing material (control).

1.8 Research Method

For this research, the appropriate research methodology adopted for this study is experiment. There are four main components to be considered in this experimental method which are participants, materials, procedures and measure. The specific procedure applied in this study is Pre-experimental design, particularly for Static-Group Comparison. This procedure is chosen due to the relevancy and applicable procedure in order to achieve the study's main goal. Basically, this procedure suggests the experimenters to apply a verification technique after implementing a treatment. A comparison group is then selected and finally a posttest is conducted towards both experimental and comparison groups.

1.9 Chapters Overview

This subtopic explains briefly on the whole chapters included in this thesis. For the first chapter, it's about the general introduction to what this study is all about, which is the utilization of natural fibre as a reinforcement matrix in composite to be applied in prosthesis manufacturing.

In the second chapter which is literature review, it discusses further on all the aspects that should be taken into account in order to achieve the overall goal of this study. The aim of the review is to evaluate and show the relationships between the work already done, and the current work and how the work adds to the research already carried out.

Research Methodology is the topic to be revealed in the third chapter. Section 3.1 reveals the techniques and processes required in the preparing the materials before the test. The control composite represents the existing laminated composite structure to fabricate socket and it will be compared mechanically and physically with the three proposed laminated composites. Then, this chapter explains the method used to verify the results, which is basically based on the mechanical and physical properties.

In Chapter 4; results and discussion, all the data collected from the experiments and lab testing are presented and discussed. Validation process transpire here which mostly conferred on how the data could affect the results and what could cause it.

The last chapter in this thesis is conclusion and recommendation. This chapter discusses how the researcher answers those research questions of the study. Finally, it goes on the recommendations for the future study and these recommendations are based on limitations and the uncovered aspects out of this research.

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BIODATA OF STUDENT

On 22nd May 1987, in Felda Jengka settlement in Pahang, I was born and named Rosalam Che Me. My father, Che Me Bin Awang Cha is a FELDA settler and my mother, Che Sam Binti Omar is a full-time housewife.

For now, I'm a post-graduate student in Master of Science (Biocomposite Product Design) attached to the Institute of Tropical Forestry and Forest Product (INTROP), Universiti Putra Malaysia. My master thesis entitled "Woven Kenaf Bast Fibre: An Alternative for Glass Fibre Stockinette in the Laminated Composite Structure for Prosthetic Leg Socket Fabrication". An article related to my thesis is published in Alam Cipta Journal, one chapter in book (published by INTROP) and one proceeding paper in SAMPE international Journal.

I have also prepared a prototype out of the finding and submitted it for patent filing. Towards completing of this research, I was assisted by my supervisory committee; Prof Dr Rahinah Ibrahim (main) from Faculty of Design & Architecture and Prof Dr Paridah Tahir (Co) from INTROP, UPM. I have to admit, without their assistance and dedicated commitment, I could not complete this research.

Right after finishing my secondary level studies, Mara Junior Science College in Kuantan, I entered UPM. I hold a Bachelor of Design, Industrial Design from the Faculty of Design & Architecture, UPM in 2009. The greatest achievement is when my Final Year Project, entitled Mobile Cubicle Cell (MC^2) won a silver medal in Pameran Reka Cipta, Penyelidikan & Inovasi

(PRPI) 2011. On top of that, I also grabbed as Innovative Designer for the year of 2009 from my department.

My hobby include art, design, architecture, technology, transportation, gadgets and science. And I also enjoy music, internet browsing, movies, travelling and outdoors and extreme activities. I am good at communication skills, independent, fast learner and always forward looking in all aspects of life.

During my master's studies, I was employed as a Research Assistant and was involved in design, 3D construction of the prototype model and visualized it into scaled product using Rapid Prototyping (RP) machine. I have also employed as designer in an event management and exhibition company. Apart from that I was also hired as a book design consultant and produced 160 books which were published in Indonesia. Currently, I'm working as a designer cum detailer in a well-established kitchen cabinet company.

My future plan is to further my doctoral studies and be involved in the academic scenario for the benefits of the nation and ummah in general.