UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

JUTE/GLASS REINFORCED POLYESTER RESIN LAMINATED COMPOSITE BY COMPRESSIVE MOULDING: MECHANICAL PROPERTIES BASED ON DIFFERENT STACKING SEQUENCE AND SURFACE TREATMENT

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Master of Manufacturing Engineering (Industrial Engineering)

2014

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Manufacturing Engineering (Industrial Engineering)

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DECLARATION

I hereby, declared this report entitled 'Jute/Glass Reinforced Polyester Resin Laminated Composite By Compressive Moulding: Mechanical Properties Based On Different Stacking Sequence And Surface Treatment' is the results of my own research except as cited in the references.

Signature : ....

Author's name : Siti Fatimah Bt Abait

Date : 26th August 2014

DEDICATION

Dedicated to my beloved husband Jas Rimi Bin Jaapar, my son Widad Darwish and daughter Jasmin Hanna for giving me moral support, encouragement and strength. Also, I dedicated to my mother, Salmah Bt Shuib who always pray for my success. Special thanks to Dr. Mohd Asyadi 'Azam Bin Mohd Abid for patiently supervised until completing the research. Not to forget, to all colleagues and friends who always encouraged towards the end.

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for award Master of Manufacturing Engineering (Industrial Engineering).

Signature : ---

Supervisor name: Dr. Mohd Asyadi 'Azam Bin Mohd Abid

Date : 28/8/2014

ABSTRACT

Effect of stacking sequence, NaOH and silane treatment on tensile and flexural properties of jute glass fibre polymer composites have been evaluated experimentally. Jute fibres were subjected to 5% NaOH solution treatment for 24 hours and 1% of silane solution treatment at 2 hours. All laminates with a 5 total plies, by varying the number and sequence of glass and jute fibre as to obtain 6 different stacking sequences. All jute and all glass fibre also had been prepared for the comparison purpose. Laminate were fabricated by compressing method at 40°C for 30 minutes, followed by curing at room temperature for 24 hours. Specimen preparation and testing was conducted as per ASTM standards. A test was conducted using an Instron UTM machine at room temperature. The result indicated that the suitable laminating hybrid configuration of the composite by placing fibre mat at different sequence and stack could improve the mechanical properties. An overall comparison, the hybrid composite with 3 plies of glass fibre treated with NaOH was the optimum combination with a good balance between properties and cost.

ABSTRAK

Kesan urutan menyusun, NaOH dan rawatan silane pada tegangan dan lenturan sifat-sifat komposit polimer gentian kaca jut telah dinilai uji kaji. Gentian jut tertakluk kepada 5% NaOH rawatan larutan selama 24 jam dan 1% daripada rawatan penyelesaian silane di 2 jam. Semua lamina dengan 5 jumlah lapisan, dengan mengubah bilangan dan urutan kaca dan gentian jut untuk memperolehi 6 urutan tindanan berbeza. Semua jut dan semua gentian kaca juga telah disediakan untuk tujuan perbandingan. Lamina telah direka oleh memampatkan kaedah pada 40 ^{o} C selama 30 minit, diikuti dengan menyembuhkan pada suhu bilik selama 24 jam. Penyediaan spesimen dan ujian telah dijalankan sebagai satu piawaian ASTM. Ujian telah dijalankan menggunakan mesin Instron UTM pada suhu bilik. Hasilnya menunjukkan bahawa konfigurasi lamina komposit hibrid dengan meletakkan tikar serat pada urutan yang berbeza boleh meningkatkan sifat-sifat mekanikal. Satu perbandingan keseluruhan, komposit hibrid dengan 3 lapisan gentian kaca dirawat dengan NaOH adalah kombinasi yang optimum dengan keseimbangan yang baik antara sifat dan kos.

ACKNOWLEDGEMENT

First of all, I would like to express my gratitiude to Allah S.W.T, for giving me the strength, infinite grace, love and blessing tthroughout the entire time until the completion of this Master Project Report. Peace be upon our prophet Muhammad S.A.W, whose has given light to mankind.

In preparing this Master Project, I was in contact with many peoples, researchers, academia and practitioners. They have contributed towards my understanding and thought. In particular, I would like to express my most sincere and my deepest gratitude to my supervisor Dr. Mohd. Asyadi 'Azam Bin Mohd Abid. I have been really fortunate and very thankful to have a kind, tactful, patient and an understanding supervisor throughout this Master Project study.

My sincere appreciation also extends to all my colleagues and others who have provided assistance at various locations. Their views and tips are useful indeed.

Last but not least, I would like to express my thanks as well as my apologies to my son, Widad Darwish and Jasmin Hanna and especially to my husband, Jas Rimi, for his untiring encouragement, trust, patience and understanding during the 2 years studies.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Technological development together with consumer expectation, great pressure from activist and preservation of natural resources, leading to the development and invention of natural fibre. Natural fibre composites offer better mechanical properties, low density, biodegradability, acceptable specific properties better thermal insulating properties, low energy consumption during processing and low price. Natural fibre composites are well suited for use in the worldwide automotive industry, which has come under strong pressure to produce environmentally friendly cars. In Europe, natural fibres are gradually used in the production of substrate materials for automotive interior parts such as door liners and head-liners. Besides, applications in the automotive industry, the technology can also be used to manufacture panelling and furniture components and in thicker beams that could be used in outdoor railings and decking. Plant based natural fibres reinforcement include flax, hemp, jute, sisal, kenaf, coir, kapok, banana, bagasse and many others. However the natural fibres has certain disadvantages, such as compatibility with the hydrophobic polymer matrices, the tendency to form aggregates during processing, and poor resistance to moisture absorption, reduce significantly the mechanical properties of the natural fibres reinforced composite materials (Mohanty et al., 2005). The mechanical properties of natural fibre composites can be improved by hybridizing them with glass fibre or natural fibre of superior mechanical properties. Although the biodegradability of the composite is reduced, this can balance the advantages gained by the increase in mechanical properties. Hybrid composite can achieve more favourable balance between the advantages and disadvantages characteristic in any composite material.

In the study, jute/glass fibres were combined in the same matrix to produce hybrid composites. By following the stacking sequence of jute fibre polymer composites, jute/glass/jute reinforced polymer composites, glass/jute/glass reinforced polymer composite and fibreglass polymer composites were fabricated by using compression moulding technique. The mechanical properties were studied by conducting tensile and flexural test using Universal Testing Machine. The samples were prepared according to ASTM standard. The effect of fibre-matrix bonding and breakage of the composite was analysed with the help of Optical microscope (OM). Table 1.1 shows the mechanical properties of jute and glass fibre (Mishra 2013).

Table 1.1: Mechanical properties of jute and glass fibre *(Source: Mishra 2013)*

Properties	Jute	Glass
Density (gm/cc)	1.3	2.5
Young's modulus (MN/m2)	72	55.5
Moisture absorption after 24 hrs (%)	6.9	0.5
Aspect ratio	152-365	100-140
Specific gravity (gm/cc)	1.3	2.5
Tensile strength (MN/m2)	3400	442
Specific modulus (GN/m2)	28.8	42.7

1.2 Problem statement

The applications of composite materials are extensively used nowadays using fibres with unsaturated polyester resin. However, the utilization of synthetic fibres for many years is potential to affect the environment and depleting the petroleum resources. This type of fibre also expensive compared to natural fibre. Nevertheless, the mechanical properties of natural composites are much lower than the synthetic fibre composite (Muthuvel et al., 2013). The natural fibre polymer composite alone will enhance the lack of properties by the single fibre alone. The applications of natural fibre polymer composite are somehow limited because of their moderate strength and high moisture. However, synthetic fibre alone, such as glass fibre also has its sphere limitation.

Hybridization between glass/jute fibres will compensate the weakness of the sole fibre as well as to confront with the environmental concerns such as incapability to recycle and bio-degradable issues. Furthermore, mechanical properties of glass/jute fibres will be enhanced since jute fibre will confront the weakness of glass fibre and vice versa. In addition, the usage of natural fibres in composite applications, especially in Malaysia is relatively low. The costs of natural fibre are cheaper and cost effective than using synthetic fibre. Even though, the properties of natural fibre are lower than synthetic fibre, but the advantages of natural fibre are low cost and biodegradability. Hence, this research was in attempted to improve the hybrid configuration with different stacking sequence and surface treatment of mat using jute fibre as a natural resource fibre as well as fibre glass in hybrid composite to discover its contribution in improving the mechanical properties of composite materials via tensile and flexural test.

1.3 Aim and Objective

The aims of this research are:

i) To fabricate jute fibreglass hybrid composite by using compression moulding technique with different stacking sequence and surface treatment.
ii) To characterize the mechanical and morphological properties.

1.4 Scope of study

In order to achieve the objectives this research is focusing on the following scopes:

For objective i:

i) Fabricate jute glass, jute/glass/jute, glass/jute/glass and glass reinforced polymer composites with different stacking sequences.
ii) Immersed jute fibre with silane coupling agent, 3-aminopropyl triethoxysilane blended into 50% of acetone and 50% of water, the percentage of silane is 1% for 2 hours.
iii) Then the jute was cleaned with acetone and dried under the sun for 8 hours.
iv) Jute was cleaned and soaked in 5% NaOH solution for 24 hours at room temperature. Then, thoroughly washed jute with water tap. Finally, the treated jute fibre was placed under the sun for drying purpose.

For objective ii:

i) Observed the surface morphology of the sample using Optical Microscopy (OM).

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Technological development connected with consumer demands and expectations continues to increase demands on global resources, leading to major issues of availability of materials and environmental sustainability. This century could be called cellulosic century because more and more renewable plant resources for products are being discovered, developed and consequently applied. Natural fibres have already recognized world widely as reinforcing materials with a great environmental friendly and ecological concerns in producing green products. The promising of properties of natural fibre-reinforced composites such as reduction in density of products, acceptable specific strength, toughness, and stiffness in comparison with synthetic fibre-reinforced composites, lower energy consumption of fibre growing to finished composites, the safety factor in health, and low capital investment make them accepted in engineering market such as automotive and construction industries.

Natural fibres such as jute, flax, hemp, bamboo, kenaf, coir, silk, have its own drawback, but the combination with synthetic fibres appear to be outstanding structural materials that are feasible and abundant reinforcement for the replacement of expensive and non-renewable synthetic fibre.

2.1 Natural Fibre

Recently, researchers are focused more on natural fibre since the advantages of natural glass fibre that can be renewed and they are abundant from nature. Besides that, the usage of natural fibre also keeps the health of the workers in a good condition. Natural fibre offers good thermal properties and excellent acoustic performance (Yongli et al., 2013). Researchers put a lot of work with different approaches in increasing the mechanical properties and physical properties of natural fibre composite, whereas the physical or chemical modification of the matrix and fibre of natural fibre has been investigated (Yongli et al., 2013). Several natural fibre composites reach the mechanical properties of glass-fibre composites, and they are already applied, e.g. in the automobile and furniture industries.

2.1.1 Hemp

Hemp is one of the oldest and most useful economic plants. Hemp is a tall, fast growing annual plant of the *Cannabaceae* family has various names such as marijuana, hash, pot, weed, grass, dope, Indian hemp and all referring to the same plant, *Cannabis sativa L.* Shahzad (2011) showed considerable improvement in the tensile properties of the hemp skin-glass fibre composites compared to hemp composites. The hybridization of low strain to failure fibre with a high strain to failure, fire results in an enhancing the failure strain of the composites.

Figure 2.1: Hemp fibre *(Source: http://hempforyou.com)*

2.1.2 Kenaf

Hibiscus Cannabinus L. known as kenaf, a native plant of east-central Africa is a wild plant that has been grown thousands of years for sources of foods and fibres. The growth of the plant at height of 4-5m within 4-5 months can produce products similar to the wood. Kenaf is used as a cordage fibre in the manufacture of rope, twine carpet backing and burlap. Due to its properties of low density, non-abrasiveness during processing, high specific mechanical properties and biodegradability kenaf becomes a substitute in for synthetic fibres and can be found more in automotive industry producing automobile dashboard, carpet padding and others. The combination of long kenaf woven-fibre in fabricating the hybrid composites produces the maximum mechanical properties (Salleh et al., 2012). He suggested that long kenaf/woven fibre hybrid composites have the potential to be used in many applications for non-critical stress bearing structures to replace the glass fibre composites.

2.1.3 Flax

Flax Linum Usitatissimum is one of the oldest fibre crop in this world and is grown in temperate region and is always used in textile market, however, today flax have been widely used in the composite area (Faruk et al., 2012). The effect of the hybrid ratio of the tensile strength of flax –glass fibre reinforced hybrid composite showed the tensile strength increased with the increasing of the relative volume content of glass fibres. If the volume fraction of flax fibres in hybrid composite was high, the hybrid composite would fail when the tensile strain reached the failure elongation of flax fibre reinforced polymer.

2.1.4 Jute

Jute is known as *genus corchorus* with 100 species grown in Bangladesh, India and China is the cheapest natural fibre and currently the bast fibre with the highest production volume (Faruk et al., 2012). Jute as a natural fibre is eco-friendly, low cost, versatile in textile fields and has moderate mechanical properties, which replaced several synthetic fibres in development of many composite materials. However, the hydrophilic nature of the jute fibre affects the mechanical properties of the developed composites. Another important issue to note that the tensile strength of jute fibre is extremely defect and span sensitive. Jute fibre contains 82–85% of holocellulose of which 58–63% is a-cellulose. Jute fibre presents some disadvantages such as high moisture sorption, poor dimensional stability, intrinsic polarity, low thermal resistance, anisotropic fibre resistance, and variability. Mishra et al., (2013) conducted corrosion test by soaking in brine solution and he predicted that the jute glass epoxy composite underwent reduction for a small period of time initially and oxidation. Therefore, from the results suggest that this type of composite is not suitable for use in the marine environment. Apart from much lower cost and less energy required for the production of jute (only 2% of that for glass) makes it attractive as a reinforcing fibre in composites. According to Boopalan et al., (2013), the hybrid composite of jute/banana fibre reinforced epoxy, 50/50 by weight ratio gave a high result of tensile and flexural strength compared to other ratios. Jute composites have gained huge mechanical properties over the matrix material and thus indicated good fibre matrix adhesion (Nahar et al., 2013). The SEM images of the surface fracture showed jute fibre pull-out was quite higher and the bonding between jute and polypropylene matrix was not so good (Jayabal et al., 2010).

Figure 2.2: Mature jute fibre *(Source: http://static3.depositphotos.com)*

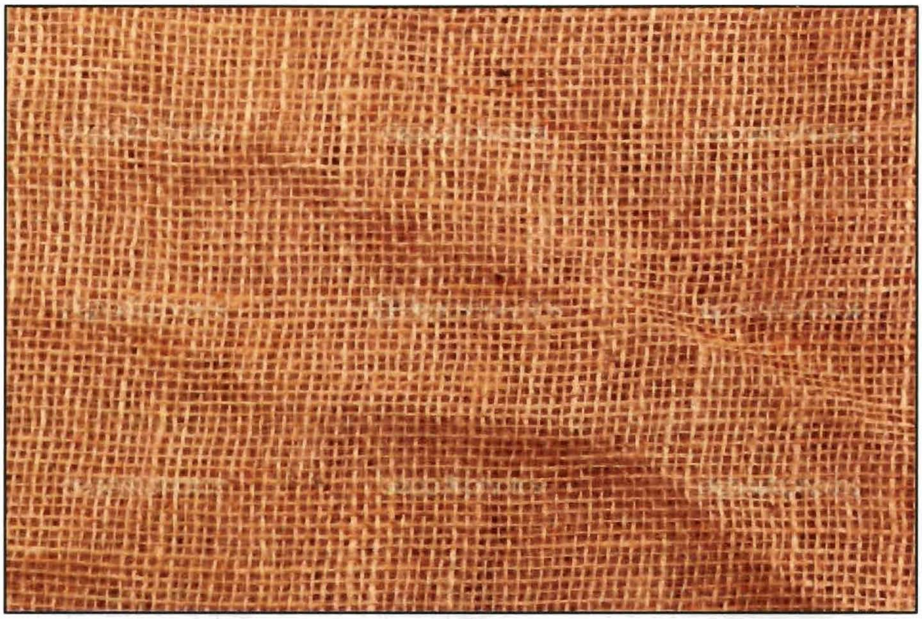

Figure 2.3: Woven jute fibre *(Source: http://static3.depositphotos.com)*

2.1.5 Sisal

Sisal fibre is one of the most widely used natural fibres and is very easily cultivated. Almost 4.5 million tonnes are produced in each year all over the world. Tanzania and Brazil are the two most important country producers. Generally the sisal fibres are defined by their source, age and cellulose content, giving it the strength and stiffness. The tensile properties of the sisal fibre are not uniform along its length. The root or lower part has low tensile strength and modulus, but high fracture strain. The fibre becomes stronger and stiffer at mid-span and the tips have moderate properties.

Figure 2.4: Mature sisal plants *(Source: http://www.arc.agric.za)*

Figure 2.5: Sisal fibre *(Source:* http://www.interplas.com*)*