UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

ANALYSIS OF WOVEN FABRIC CHARACTERISTICS FOR COMPOSITE REINFORCEMENT

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A thesis submitted in fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering with Honours

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DECLARATION

I declare that this thesis entitled "Analysis of Woven Kenaf Fabric Characteristics for Composite Reinforcement" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
Name	:	....
Date	:	....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor Mechanical Engineering with Honours.

Signature :……………………………

Supervisor Name :……………………………

Date :……………………............

ABSTRACT

Nowadays, the decrease of landfill site has become a concern in Malaysia with the ever-increasing amount of trash fully occupying limited available landfill area. Such concern has causes the industry to consider develop their product using cheap, renewable and biodegradable source. This leads to the research in usage of natural plant-based fabric in reinforcing composites. This research aims to investigate the effect of ageing, loading direction and moisture on the tensile properties of kenaf fabric. Two batch of plain woven kenaf fabric is purchased at a different time is used throughout this research. ASTM: D5035 is employed when conducting the tensile test of kenaf fabric in both the warp and weft direction. In the case of moisture condition, the kenaf fabric is tested and compared in dry and fully saturated moisture condition only. The results collected indicated that kenaf fabric exhibit better tensile properties in the weft direction in overall while age and moisture condition cause a change in strain and tensile properties.

ABSTRAK

Marcapada ini, peningkatan dalam kadar pembuangan sampah ke tapak pelupusan sampah yang terhad telah menyebabkan masalah kekurangan tapak peluspusan sampah di Malaysia. Hal ini telah menyebabkan industri bertindak untuk menghasilkan produk menggunakan bahan yang lebih murah, boleh diperbaharui dan dibiodegradasi. Oleh itu, pelbagai pengajian mengenai penggunaan kain berdasarkan serat tumbuhan sebagai bahan penguat untuk komposit telah dijalankan. Kajian ini bertujuan untuk mengenalpasti kesan lokasi penempatan beban, masa penyimpanan dan kelembapan terhadap kekuatan tegangan kain kanabis. Kajian ini secara keseluruhannya dijalankan menggunakan dua bidang kain kanabis yang dibeli daripada masa yang berbeza. Kekuatan tegangan kain tersebut telah dikaji berdasarkan ASTM: D5035 melalui penempatan beban pada arah pakan dan lungsin kain tersebut. Kesan kelembapan kain pula dijalankan dengan membandingkan kekuatan tegangan kain dalam keadaan yang kering dan basah sahaja. Hasil kajian menunjukkan bahawa kain kanabis mempunyai kekuatan tegangan yang lebih besar dalam arah lungsin berbanding dengan arah pakan manakala jangka masa penyimpanan dan kelembapan kain telah menyebabkan perubahan kekuatan dari segi kekentalan dan tegangan kain kanabis.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Lately, the issue of environmental pollution is highlighted by the public due to the increase of global temperature, decreased land and the effect of the pollution towards the sustainability of endangered wildlife and plants. In Malaysia, the problem of decrease in landfill area for solid waste disposal has increased public awareness in environment sustainability issues. To overcome these environmental challenge, researchers have been proactively looking for solution to overcome these adverse effects for the sake of sustainability of natural resources and mankind. Various approaches have been taken to allow biodegradation of daily used products such as plastic bags and fabrics to further reduce the landfill and treatment needed from disposal of such items. The introduction of using biodegradable materials to manufacture human daily used products will significantly reduce the landfills caused by disposal of these products while providing a better and cleaner environment. Biodegradable materials like hemp, sisal, cotton and bamboo fibres are thoroughly researched in manufacture of various product and bio-composites, but not much research has been done on kenaf (*Hibiscus Cannabinus L*) fabric and its uses in manufacturing industry.

6000 years ago, kenaf had been cultivated by Afrika farmers as cordage crop and livestock feed for various husbandry purpose (Dempsey, 1975). Since then, little technology and research regarding the usefulness of kenaf has been done throughout these centuries where most of the research were focused in textile industry. With the global mind attempts to perform sustainable development, manufacturing industries are encouraged to adopt new, biodegradable materials in the place of non-renewable resources in manufacturing products. This can be seen in the Mediterranean paper and textile industry where kenaf has been used in pulp production to replace wood in the manufacturing process (Ardente et al., 2008). Kenaf bast fibres have also been extracted to be used in reinforcement of thermoplastic composites. The advancement of technology and research allow kenaf plant to be one of the primary economy crops for farmers with its wide uses by the various industry.

Despite all the uses that can be provided by kenaf plant, the fabric produced has been mainly used as is without considering its possibility in composite reinforcement. The property of kenaf fabric allow it to be used as food safe package for fruits and vegetables. However, the mechanical properties of this material under different conditions are not researched by most researchers worldwide. The relationship of moisture, age, temperature and orientation of fibres with its mechanical properties can provide insight in discovering new application for this material.

The application of kenaf in production of papers and textiles generally means that it will be exposed to water during its working condition whether as a bag or straps. The changes in its mechanical properties should be identified to ensure that the product will be safe to use while having a longer lifespan. Most natural fibre might swell when exposed to moisture which could affect its mechanical properties. Such phenomenon should be investigated to determine its effect on the appearance, chemical properties and mechanical properties to further prolong its lifespan to prevent waste.

Just in time production concept suggest that some of the produced product need to be stored as surplus stock to meet the demand of customer at any time. The extra product produced needs to be stored properly for unknown duration until a requested from customer has been received. The effect of storage duration or time on the fabric also needs to be investigated to ensure the quality of the fabric. The fabric might be undergone decomposition or bug infestation throughout its storage time. This could impact the quality of the fabric in terms of tensile properties and general appearance. The results from this investigation could help the manufacturer to determine the quality of the fabric to protect its company reputation. Manufacturer could also ensure the quality of their product that uses kenaf fabric as base material.

1.2 Problem Statement

The mechanical properties of kenaf as reinforcement fibre in bio composite have been widely researched for its reinforcement effect on the composite. However, the research about the properties of kenaf fabric itself is still lacking in a lot of aspects. Kenaf fabric has a lot of potential as the base material for biodegradable composite or simply as the reinforcement layer for metal or plastic composite. Kenaf fabric has some other uses besides its role in composite such the manufacture of biodegradable bags and low-cost packaging for fresh crops and plants. The basic mechanical properties of kenaf fabric is usually provided in the datasheet by the manufacturer which includes the weight and density of the fabric in overall, tensile strength of the fabric and the amount of yarn in the fabric. The absence of its mechanical properties under different condition limit its uses in developing and designing new product.

For fabric, its most common application lies in packaging of products and as base material for clothes which is usually susceptible to tension and moisture. Most research today mainly focus on the reinforcement capability of the material in its bio composite. The effect of moisture content in kenaf fabric towards its tensile properties remains unknown by many which cause the material not to be considered when deciding material to be use in product development.

The effect of age or time of the fabric towards its mechanical properties is one interesting topic not considered in most other research. The packaging of the product is generally needed to be long lasting and durable to protect the packaged product from any external damage. External interference to the packaging can comes in physical and chemical form such as bug bites, damage from pest such as mice, moisture absorption from exposure to rain and chemical exposure from leakage in other products such as detergents, juices or ink for marking purpose. Such research provides us an insight regarding the quality of the stored fabric whether it can still be used for its decided purpose.

Thus, the main problem statement to be solved by this research is:

- What is the effect of moisture to the tensile properties of kenaf fabric?
- What is the effect of time or age of the fabric in its tensile properties?

1.3 Objective

Based on the problem statement mentioned in the last section of this proposal, this research aims at discovering the effect of moisture content in the tensile properties of kenaf fabric. The objectives for this research are:

- To investigate the tensile properties of kenaf fabric with different moisture content
- To research the tensile properties of kenaf fabric with different age or storage time

1.4 Scope of Project

The scopes of this project are:

1. This research focuses on the fabric properties and the changes in tensile properties based on selected criteria of kenaf fabric only.
2. Only plain woven weave structure fabric is used in this research.

3. The research aims to identify the effect of age and moisture on the tensile properties of kenaf fabric.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The reinforcement of composite using woven fabric is widely practiced nowadays by manufacturers to reduce production cost and sustainability of the product. Reinforcement of composite using kenaf is especially cheaper compared to synthetic fibres such as glass fibres considering the amount of energy and additional cost required to produce and process the synthetic fibres. As an evidence, 1kg of kenaf only required 15MJ of energy in production while glass fibres require a total of 54MJ of energy to be consumed for each kilogram produced (Nishino, T. 2004). Being a fast-growing crop, kenaf only takes 3 months to mature and having an annual yield up to 10000kg/ha, kenaf has been proven to have a constant supply throughout the years (S. K. Ramamoorthy et. al., 2015). Kenaf generally requires a hot and humid environment to cultivate successfully. Such environmental condition is nicely inclined with the environmental condition in Malaysia, which only have sunny and rainy weather. Such environmental condition coupled with easy cultivation of kenaf plant, Malaysia farmer are generally encouraged to cultivate this economy crop in their field. Composite reinforced using natural fibres such as kenaf and hemp has improved sustainability due to its biodegradable property. However, the incorporation of natural fibres into composite is not without its flaw. Some of the limitation of using natural fibres in reinforcing composite includes decreased mechanical and thermal properties due to low thermal resistance and hydrophilic properties of natural fibres, anisotropic properties and poor adhesion between the natural fibre and composite matrix (Celino et. al., 2014). Thus, researchers have been investigating various properties of natural fibres that could contribute or impair the overall performance of the resulted bio-composite using natural fibres.

2.2 Chemical Composition and Structural Organization of Kenaf

The structural and chemical composition of kenaf contribute to its mechanical and thermal advantages over other natural fibres. Kenaf fibres are characterised as a bast fibres which are fibres collected from the stem or phloem of the plant. Being a plant based fibre, the major chemical component of kenaf is lignocellulose (cellulose, hemicellulose and lignin) where these component is different from one plant to another plant (Ramamoorthy et. al., 2015). Lignocellulose is a linkage of cellulose and hemicellulose that are joint together by lignin. Such component coupled with pectin and protein provide the mechanical support for most plant cell. Cellulose provides the strength and stiffness of a plant fibre which is made up from linear 1,4-β-glucan polymer consisting D-anhydroglucose ($C_6H_{11}O_5$) that contain the hydrophilic hydroxy groups (OH). Such chemical structure causes most plant fiber to be hydrophilic in nature. Figure 2.1 shows the chemical structure of a cellulose. A summary of chemical component present in kenaf fibres from various parts is shown in Table 2.1

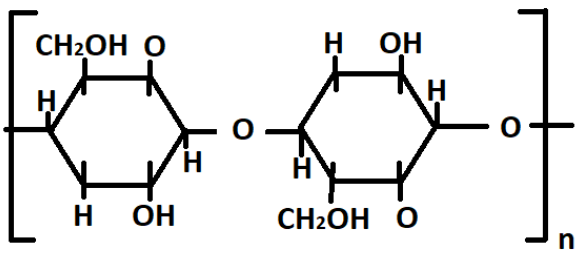

Figure 2.1: Chemical structure of cellulose

Table 2.1: Chemical composition of different fractions of kenaf fibre (Abdul Khalil et. al., 2010)

	Kenaf whole (core + bast)	Kenaf core	Kenaf bast
Extractive (%)	6.4	4.7	5.5
Hemicellulose (%)	87.7	87.2	86.8
α-Cellulose (%)	53.8	49.0	55.0

Lignin (%)	21.2	19.2	14.7
Ash (%)	4.0	1.9	5.4

In the table, hemicellulose is the collection of cellulose and hemicellulose without any other extractives, lignin and ash in a plant fibre. α-cellulose on the other hand is the major component found in wood and paper pulp. This component provides the high strength in most fibre-based product (Ayadi et al., 2016). As can be seen in Table 2.1, the kenaf bast has the highest α-cellulose compared to fibres extracted from other region of the plant. This result indicates that kenaf bast fibres are the most suitable fibres to be used in textiles and reinforcement of bio-composites due to their higher strength. The chemical composition of kenaf is also susceptible to change in regional environment condition such as regional temperature, soil condition and air humidity. Thus, it is logical to think that the chemical composition of kenaf originated from Afrika to be different with ones cultivated locally in Malaysia. According to Ashori et al. (2016), the Malaysia cultivated kenaf bast fibres have lower lignocellulose material compared to the core fibres. Results from Ashori et al. (2016) also showed that the chemical composition of kenaf is different in amount when compared to research data collected by other party from another country. A summary of Malaysia cultivated kenaf chemical composition is shown below:

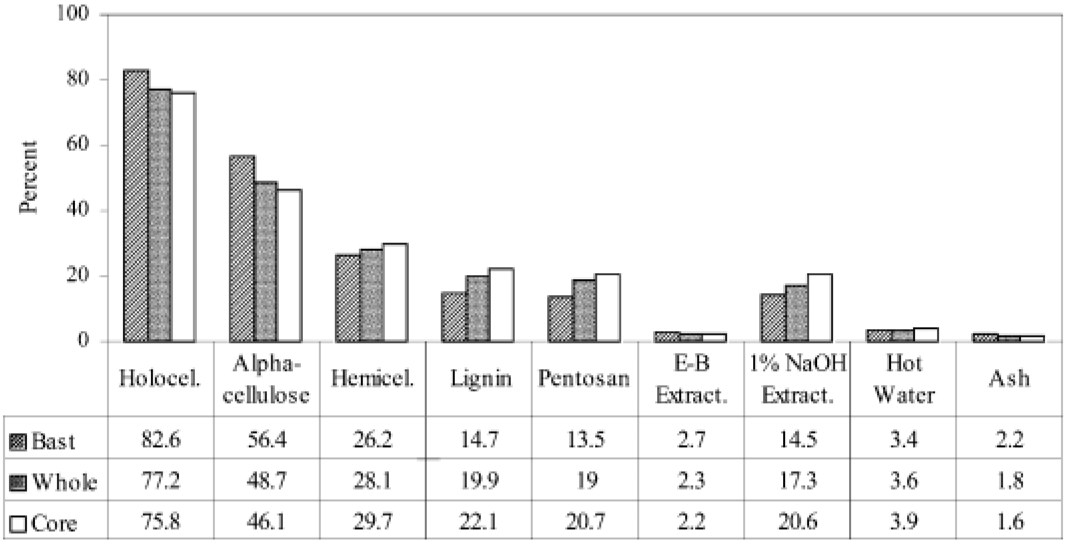

Figure 2.2: Chemical composition of Malaysia cultivated kenaf in different fraction (Ashori et al., 2006)

When comparing kenaf fibres with other bast fibres, Ramamoorthy, Skrifvars & Persson (2015) reported that kenaf has the lowest cellulose content (31-39%) and the highest lignin content (15-19%) among the other bast fibres such as hemp, jute and ramie. Such characteristic of kenaf indicates its potential as reinforcement material in composite manufacturing. The chemical composition of some bast fibres are shown in Table 2.2.

Table 2.2: Chemical composition of some bast natural fibres (Ramamoorthy et al., 2015)

Fibre	Cellulose (wt%)	Lignin (wt%)	Hemicellulose (wt%)	Wax (wt%)
Flax	71.0	2.2	18.6-20.6	1.7
Hemp	70.2-74.4	3.7-5.7	17.9-22.4	0.8
Jute	61.0-71.5	12.0-13.0	13.6-20.4	0.5
Kenaf	31.0-39.0	15.0-19.0	21.5	-
Ramie	68.6-76.2	0.6-0.7	13.1-16.7	0.3

In terms of structural organization, plant fibres generally have a multi-scale structure which can be used at various scales for composite reinforcement. The construction of plant fibre yarn contains a large number of short fibres that are twisted together at an angle to provide substantial strength to the yarn (Madsen et al., 2007). Thus, the strength of yarn can be traced back to a single unit fibre. Past research has shown that unit fiber has multiple cell wall and a polygonal cross-section which is normally assumed to be circular to simplify calculation of stress in plant fibres. The unit fibre has a lumen which gives a hollow structure, a thin external cell wall which made up of pectin, low crystalline cellulose, hemicellulose and low amount of wax and a thick secondary cell wall which have microfibrils oriented parallel to each other. The secondary cell wall can be divided into three layers which has different thicknesses, microfibril twist angle and chemical composition. The mechanical properties of unit fiber are largely dependent on the second layer which made up about 80% of the secondary cell wall thickness (Celino et al., 2014). Figure 2.3 below shows the structure and chemical composition of a single fiber or unit fiber cell.

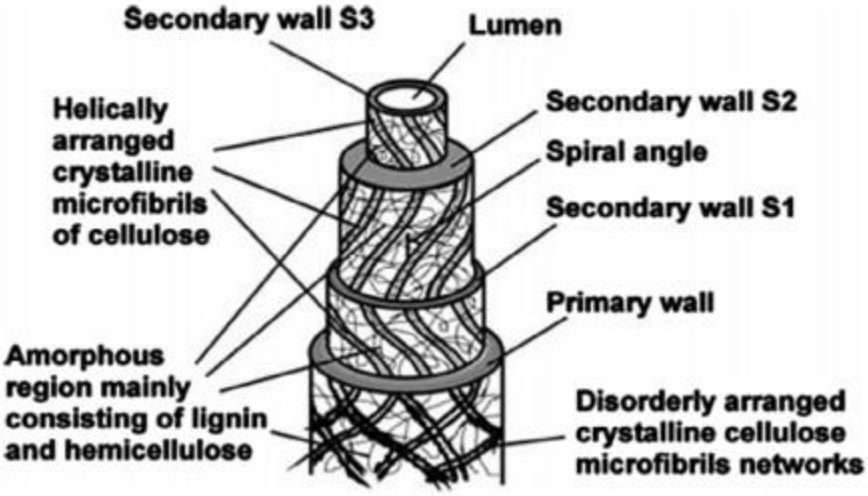

Figure 2.3: Structure of a single fiber cell (M.Ramesh, 2016)

2.3 Effect of Woven Fabric Properties in Fabric Reinforced Composite

The properties of woven fabrics depend on fabric crimp, tensile property of fabric and weaving structure of fabric. Fabric behaves differently when subjected to load compared to rigid material like wood and metal due to the woven structure used in arranging or weaving the yarns into textiles. Research has been done over the decades to identify the strength and weakness of each factor in enhancing the performance and usage of natural fibre fabric.

2.3.1 Tensile properties of fabric

The tensile properties of fabric can be seen from several factors which are the tensile strength of yarn, fabric density or linear density of yarn and the effect of crimp percentage on fabric. The strength of yarn originated from the chemical composition of fibre. When a plant fibre is subjected to a load, the applied stress starts to disturb the amorphous part of the molecular structure of the fibre by stretching the primary and secondary bond (Annis, 2012). If the loading is removed from the fibre at this stage, the fibre will show elastic behaviour by recover from its achieved extension due to loading (E.M. Abou-Taleb, 2014). As the loading continue to increase, plastic deformation occurs as the long chain of cellulose molecule rearrange reciprocally as a consequence of missing secondary bonding. However, further increasing the load will then increase the elongation of these bond and subsequently break the chemical bond and causes rupture to the yarn.

In the case of fabric density, fabric density is defined as the amount of yarn present per unit length in the fabric. This factor is also known as fabric compactness and yarn spacing. Due to anisotropy property of fabric, fabric density is determined based in the direction of the fabric in weft and warp direction. The warp can be identified as the yarns that are I parallel with the selvages on the fabric while weft or filling is the yarns perpendicular to the selvages or warp yarn. According to ASTM: D3776, Standard Test Method for Warp End Count and Filling Pick Count of Woven Fabric, the fabric density of a fabric is normally determined by counting the number of yarn in warp and weft direction in 1cm. Based on M.M. Islam et al. (2014), the distribution of fibre per unit area in a plate is not easy to control when using short fibre as this could result in inconsistency in density and fibre volume fraction of composite. Such concern can be overcome when manufacturing composite using natural fibre by using woven fabric with constant fibre density where the fabric density can be easily determined. S.F. Eryuruk and F. Kalaoglu (2015) reported that the tearing strength value of weft is higher than warp in their research. The densities of warp and weft also plays a role in deciding the tensile strength of fabric. The tensile strength of fabric will be reduced if the tension of warp and weft increases during weaving which limits the extensibility of fabric (Hossain, Datta & Rahman, 2016). Tensile test in fabric can be determined using two main method, the grab test and strip test. Both tensile test specifically recommended the test to be done on both the warp and weft direction as the property and stress distribution is different in warp and weft.

Figure 2.4 shows the stress strain graph of a typical fabric. As seen in the graph, the stress strain graph of fabric can be divided into three parts. The first part is the nonlinear portion at the beginning of the graph where the decrimping and crimp interchange occurs when the fabric is in tension. In this state, the yarns in the fabric will be straightened as the decrimping and crimp interchange occurs. In the second part which is the linear portion of the graph, the yarns in the fabric have become fully straightened and will be subjected to direct loading as the tension force increases in the fabric. The yarns in the fabric will continue to extend until fracture as seen in the serrated portion in the graph. The third part in the graph lies after the peak of the stress strain graph. This portion shows irregular behaviour as the yarns in the fabric begins to fracture with increasing strength applied one by one. An increment in tensile strength is expected in this portion as the fractured yarn might entangle the adjacent yarn that obstruct the movement of the yarn. A higher force is required to fracture the yarn if it becomes entangled with the surrounding yarns as the friction between the entangled yarns reduces the effective force that put the yarn in tension.