STUDY ON MECHANICAL PROPERTIES OF ECO-FRIENDLY KENAF FIBRE REINFORCED METAL LAMINATE STRUCTURE

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This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Structure and Material)

Faculty of Mechanical Engineering

Universiti Teknikal Malaysia Melaka

JUNE 2017

SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

Signature **:……………………..**
Name of Supervisor **:……………………..**
Date **:……………………..**

DECLARATION

"I hereby declare that this research is my own except for summaries and quotations which have been duly acknowledged."

Signature :……………………..

Author :……………………..

Date :……………………..

Specially dedicated to my beloved father, my late mother, brother, sister, to all my family members, lecturers and friends.

ACKNOWLEDGEMENT

I would like to show my gratitude to Universiti Teknikal Malaysia Melaka (UTeM), Faculty of Mechanical Engineering for giving me the opportunity to do this research on my thesis. A big thanks to Dr. Sivakumar A/L Dhar Malingam as my supervisor for his advices and guidance in order to complete this thesis.

Last but not least, I would like to thanks to my mentors, friends, and family who gives their continuous encouragement, support and love in helping me to finish this research.

ABSTRACT

During the past decades, the increasing demand of high performance and lightweight materials has stimulated the development of alternative materials, namely Fibre Metal Laminate (FML) structures. FML is a sandwich structure which is formed by bonding the metallic layers with composite as core constituent by means of adhesive agent. In this study, the mechanical behaviour of FMLs with the core constituents of environmental friendly kenaf fibre reinforced polypropylene composites was studied. The FMLs were manufactured through the hot press moulding compression method where the adhesives were incorporated between metallic layers and composite. The effects of fibre compositions (50, 60, and 70 wt%), fibre lengths (30, 60, 90 mm) and chemical treatment on the mechanical responses of FML were investigated. Results revealed that the increase of fibre composition and fibre length reduces the mechanical strength of FML. Highest tensile strength of FMLs is 46.70MPa which is 50wt% with 60mm fibre length while highest flexural strength of FMLs is 86.36MPa which is 50wt% with 90mm fibre length. However, the chemical treated kenaf fibre reinforced FML showed a significant enhancement of 10% to 20% on the mechanical properties in comparison to the non-treated fibre reinforced FML.

ABSTRAK

Sepanjang dekad yang lalu, permintaan yang semakin meningkat dalam bahan yang prestasi tinggi dan lebih ringan telah merangsang pembangunan bahan-bahan alternatif iaitu logam serat lamina(FML) struktur. FML adalah struktur sandwich yang dibentuk oleh ikatan lapisan logam dengan komposit sebagai bahan teras melalui ejen pelekat. Dalam kajian ini, sifat-sifat mekanikal FMLs yang menggunakan bahan-bahan mesra alam iaitu komposit kenaf gentian bertetulang polipropilena telah dikaji. FMLs telah dihasilkan melalui kaedah "hot press" dan pelekat digabungkan antara lapisan logam dan komposit. Kesan komposisi serat (50, 60, dan 70wt%), panjang serat (30, 60, 90 mm) dan rawatan kimia ke atas reaksi mekanikal FML telah dikajikan. Hasil kajian menunjukkan bahawa peningkatan komposisi serat dan panjang gentian mengurangkan kekuatan mekanikal FML. Kekuatan tegangan tertinggi FMLs adalah 46.70MPa yang 50wt% dengan panjang gentian 60mm manakala kekuatan lenturan tertinggi FMLs adalah 86.36MPa yang 50wt% dengan panjang gentian 90mm. Walau bagaimanapun, gentian kenaf bertetulang FML yang telah dirawat oleh kaedah kimia menunjukkan peningkatan yang besar sebanyak 10% sehingga ke 20% ke atas sifat-sifat mekanikal berbanding dengan gentian yang tidak dirawat gentian kenaf bertetulang FML.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

FML	Fibre metal laminate
LKTN	National Kenaf and Tobacco Board
ASTM	American Society for Testing and Materials
SEM	Scanning Electron Microscope
CMCs	Ceramic Matrix Composites
MMCs	Metal Matrix Composites
PMCs	Polymer Matrix Composites
PP	Polypropylene
NaOH	Sodium Hydroxide
EDM	Electrical discharge machining

CHAPTER 1

INTRODUCTION

1.1 Background of study

Throughout the 20th century, laser technology to locate oil and gas deposits has been improved drastically, which causes a strong global demand on oil production. Technology in automobiles, spacecraft, electronic gadget, and power plant create a lot of pollutions from oil usage where involve air and water pollution, greenhouse effect, and ozone layer depletion.

Combustion of vehicle fuel has been identified as one of the major source of pollution. Fortunately, greenhouse effect can be controlled by reducing the gases emitted from automobiles. There are several ways to reduce the fuel consumption of automobiles, which include designing the automobile to be more aerodynamics, increasing the engine efficiency, and decreasing the weight of the automobiles. Vehicle weight reduction is an adequate idea which can be achieved by utilizing a lightweight material as the body structure of vehicle. Towards the aim of reducing the vehicle weight, sandwich structure of Fibre Metal Laminate (FML) is being proposed in automotive field. Previous study has shown 30% of weight reduction can be achieved when monolithic aluminium is replaced by glass fibre reinforced polypropylene FML (DharMalingam et al. 2014). Cheah (2010) demonstrated 10% of vehicle weight reduction can lead to 7% less fuel consumption.

Fibre metal laminates (FML) as shown in Figure 1.1 is a class of hybrid structure which is formed by bonding metallic layers to composite material using adhesive agents. In 1950, Fokker Aerostructures of Netherlands found that laminated structures can prevent rapid growth of the fatigue crack compared to the monolithic materials (Chai and Manikandan, 2014).

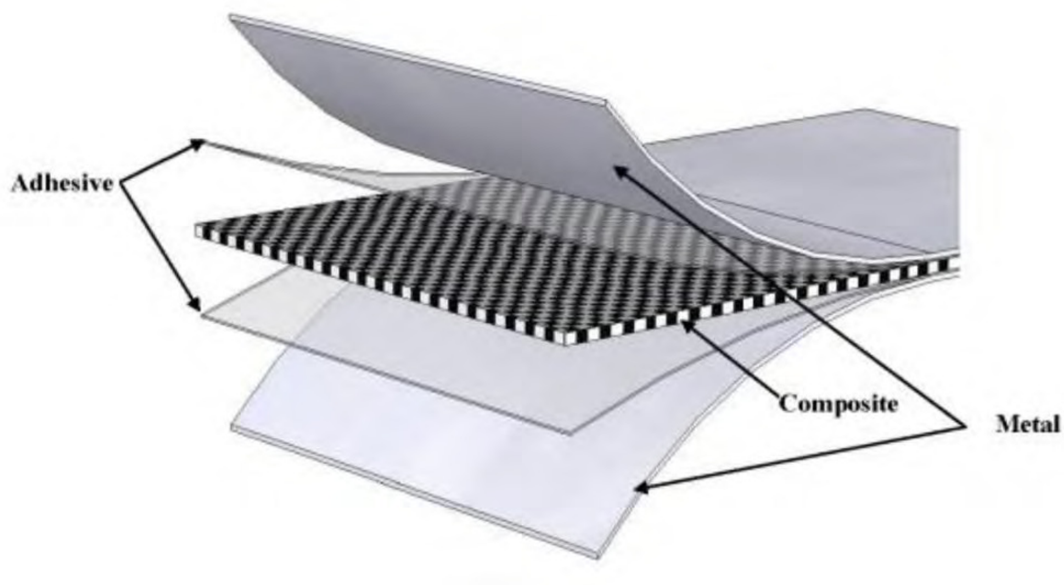

Figure 1.1: FML sandwich structure (DharMalingam and Kalyanasundaram, 2013)

The combination of composites and metals in laminated bond structures can produce a magnificent fatigue strength, impact resistance and damage tolerance. Fibre in the composite structure acts as a crack propagation retarder and increase the damping and insulation properties, while the metal layers improve ductility and impact resistance and damage tolerance (Cortes and Cantwell, 2006; Alderliesten, 2005).

Natural fibre reinforced thermoplastic composites is better than thermoset composites in terms of recyclability and processability. Thermoset matrix bring negative impacts on environmment since it is not biodegradable and recyclable whereas thermoplastic can be recycled by just heating to the melting temperature. Natural fibres such as flax, hemp, jute and kenaf fibres have been widely utilized recently due to its high availability and environmental friendly characteristic.

Kenaf fibre is from the bast and core of the kenaf plant (hibiscus cannabis L.) which constitutes 40% of the plant. Kenaf plant contains cellulose (44-575), hemi-cellulose (22-23%), lignin (15-19%), ash (2-5%), and other elements (~6%) (Kozlowski & Wladyka-Przybylak, 2008). In Malaysia, kenaf has the potential to replace local tobacco due to its high availability and ease of cultivation. The establishment of National Kenaf and Tobacco Board (LKTN) has promoted and developed the kenaf industry. To date, mechanical properties of thermoset based synthetic fibre reinforced metal laminate have been studied but there is a limited literature on the thermoplastic based natural fibre reinforced metal laminate. The mechanical performance of lightweight thermoplastic based kenaf fibre reinforced metal laminate was investigated in this study.

1.2 Problem statement

The increasing usage of fuel brought burden to environment. The fuel combustion emit harmful output that pollute the air. Since the weight of the automobiles directly affect the fuel consumption, decreasing the car body weight is crucial in order to optimise the consumption. The increasing demand in automotive and aircraft industry for lightweight structures with superior performance had stimulated the development of lightweight material such as composite structure. Current material used in automotive industries normally is steel for car bodies. The disadvantages of steel has a high expansion rate in varying temperature which causes it to crack and become deformed. FML structure of the mechanical properties will improve as the good bonding composite layer with metal skin by means of adhesive agents.

1.3 Objectives

The objectives of this research are:

i. To provide a through comparison on the tensile properties of FML with different fibre length, compositions and fibre treatment.
ii. To provide a through comparison on the flexural properties of FML with different fibre length, compositions and fibre treatment.

1.4 Scopes

The scopes of this research are:

i. To study the background literature review
ii. To fabricate and prepare the FML specimens.
iii. To conduct tensile test according to ASTM D3039.
iv. To conduct flexural test according to ASTM D790.
v. To observe and evaluate the failure mechanism of FML using Scanning Electron Microscope (SEM).

CHAPTER TWO

LITERATURE REVIEW

Literature review is a detailed and supportive information of the previous research. It is a combination of works that are related to this relevant field of the research. It proves and gives the reason to support this research theoretically. Literature review plays an important role as the future researcher able to use the provided detail and related information to support and improve the new research.

2.1 Fibre metal laminate

Fibre metal laminate is considered to be popular in recent days as many industry sectors like automotive, construction, and even aerospace are using FML to improve the material performance and reduce the cost and weight as well to reduce the unwanted greenhouse gases that can lead to air pollution. Therefore, automobiles weight reduction is the way that can be tackled down in order to improve engine efficiency. A study shows that reduction in 100kg of automobile weight can save approximate 300L to 800L fuel over the lifetime of the vehicle and this can also reduce the carbon dioxide emission to about 9g per kilometer (Helms & Lambrecht 2003).

Weight of the vehicle and usage of petroleum reduction is important indeed, however the safety of the passenger cannot be ignored. There are many years of research done to prove the advantages of FML which include high energy absorption characteristic, corrosion resistance, fire containment capacity, impact resistance and less maintenance. On top of that, duration of manufacturing of FML is simply reduced because it only need to heat up the thermoplastic composite before it is cooled down to room temperature (Carrillo & Cantwell 2009) compared to thermoset composite. This characteristic is vital as the productivity will increase if the manufacturing process time is reduced.

Fibre metal laminate (FML) is hybrid material consists of alternating layers of metal and natural fibre reinforced polymers as seen in Figure 2.1. This all began during the study to improve the crack growth properties of structural material in 1940s (C. Rans, 2007). However, the usage of the advanced aluminum alloy and fibre reinforced composite has its own advantage and disadvantage. Even both of the materials have its own weaknesses like poor fatigue strength of the aluminum alloy and the poor impact and residual strength properties of carbon fibre reinforced composites. Eventually, the thought of combining the two of the material in 1980s is to create a hybrid composite structural material to compensate weaknesses of other material (J. Laliberte, 2002). The fatigue crack growth rates can be reduced by bonding layers of material to form laminate using adhesive agent. If crack has started to grow in one of the sheet layer, the adhesive layer will act as crack divider to restrain the crack tip opening until the crack is initiate to the neighbouring layer of fibre reinforced composite too.

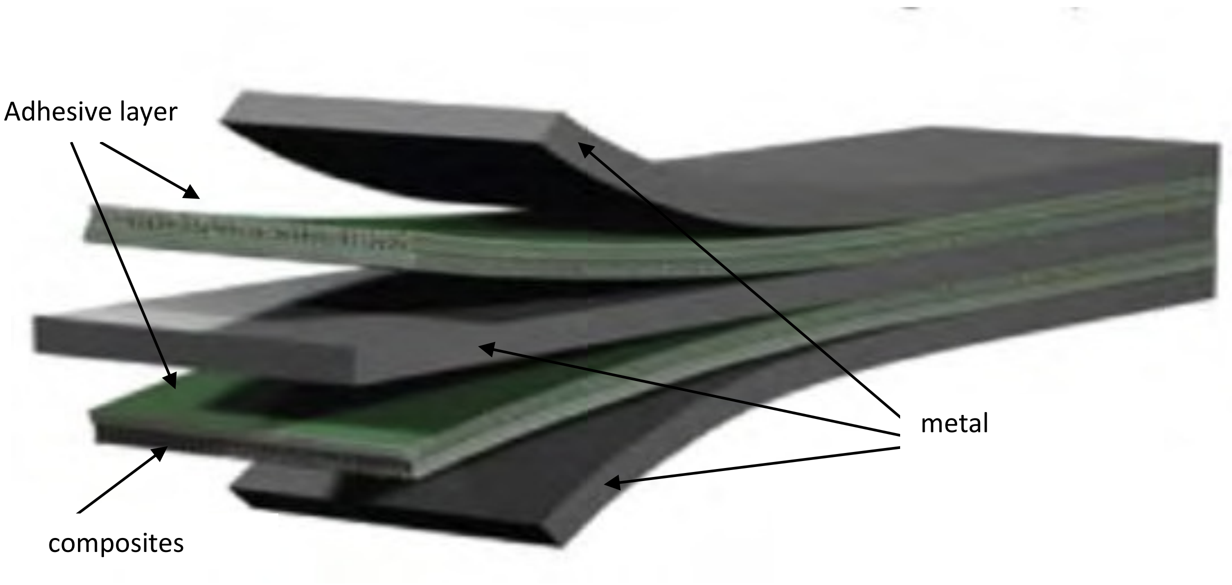

Figure 2.1: Example of fibre metal laminate (Sadighi et al, 2012)

2.2 Composite

Composite possess many mechanical advantages compared to monolithic metal. The advantages are high tensile strength and flexural strength. Composite material are defined as two or more materials combined together as a result to improve the mechanical properties compared to the original individual component (Materials & Campbell 2010).

2.2.1 Types of Composites

There are many types of composites such as Ceramic Matrix Composite (CMCs), Metal Matrix Composites (MMCs), and Polymer Matrix Composites (PMCs) (S.Kindo, 2010). Ceramic Matrix Composites are made up of ceramic matrix and fibre. Ceramic are made into fibre because it can increase the elongation resistance, thermal shock resistance and crack resistance that are normally absent in ceramic material such as glass. Ceramic fibre for CMCs normally are carbon, silicon carbide, and alumina. CMCs has the properties of light weight, high load resistance and high life cycle. Common applications used involved heat system for space vehicles, gas turbines, burners, brake disks and flame holder.

MMCs has decent properties such as high specific strength, specific stiffness, wear resistance, low density, and corrosion resistance. Since with all these good properties, MMCs composite always used in space application due to its high stiffness and almost near zero coefficient thermal expansion (Suraj Rawal, 2001).

Polymer matrix composites (PMCs) contain certain amount of fibre such as natural and synthetic fibre bonded together with matrix where polypropylene is one of the widely used matrix. PMC provides high strength, light weight, and high stiffness properties.

2.2.2 Matrix

Matrix is one of the crucial needs for composite manufacturing. Basically, the purpose of using matrix is to protect the fibres and act as bond to hold the fibre inside the composites. It allows stress transfer between the fibres in the fibre reinforced composite (Taj et al. 2007). Mechanical abrasion on the fibres surface can be avoided by using a stiffer matrix (El-Shekeil et al, 2012).

Generally, there are two types of polymer matrix which are thermoplastics and thermosets. Thermoset polymer is a network polymer which is unable to reform and reprocessed after curing. This is because the thermoset polymer form a strong covalent crosslinks between adjacent molecular chains after processing. Examples of thermoset polymer are polyester resins, epoxy and phenolic (Callister, 2007).

In contrast, thermoplastic melts when heated and harden when cooled, hence it is recyclable. This process is reversible. Common types of thermoplastic polymer are polypropylene, polyethylene, polystyrene, and polyvinyl chloride (Callister, 2007). The advantages and disadvantages of thermoset and thermoplastic are shown in the Table 2.1.

Table 2.1: Advantages and disadvantages on thermoset and thermoplastic (Rassiah & Ahmad, 2013)

Matrix	Thermoset	Thermoplastic
Advantages	1. Low viscosity 2. High adhesive with fibre 3. Excellent heat stability primal 4. Creep resistance	1. High life cycle 2. Easy to handle 3. Easy to repair 4. Recyclable
Disadvantages	1. Brittle 2. Non-recyclable 3. Unable to reform	1. Poor melt flow 2. Need to heat more than the melting point for better binding between fibre.

2.2.2.1 Polypropylene

Polypropylene (PP) is a type of thermoplastic polymer resin which is widely used in average household, commercial, and industrial application. Thermoplastic is always given a top priority than the thermoset because thermoplastic can be recycled and reused. The chemical designation is $(C_3H_6)_n$. Polypropylene is also an economical material as it offers outstanding physical, chemical, thermal and electrical properties.

PP has the properties like high rigidity and high melting point at about 157°C. Since 1957, PP became popular due to its variety of good mechanical properties and low cost. From 3rd place PP has move to 1st place by mid of 1990s (Mecharaoui, 2010). It can be reused and recycled ironically, the PP may not degrade easily inside the soil because it takes a long period for microorganism in the soil to break down the PP chemical structures. (Ammala et al. 2011). Since the PP is hydrophobic and microorganism will only attach to PP if the surface is hydrophilic. In order to increase the rate of degradation some prodegradants such as metal salts and ferrocene are added to the polymer so as to increase the rate of oxidation of polymer consequently, PP can degrade better in the soil.

2.2.3 Reinforcement

Reinforcement is one of the important materials required to produce composites. Many materials had been chosen as reinforcement such as fibre, whiskers, and fabrics. Types of reinforcement used depend on the application and situation for industry requirements. Reinforcement enhances the strength, toughness and corrosion resistance of the composite.