UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

INVESTIGATION ON THE MECHANICAL PROPERTIES OF HYBRID FIBRE METAL LAMINATE

Faizal Azli Bin Hj. Jumaat

Master of Mechanical Engineering (Automotive)

2016

INVESTIGATION ON THE MECHANICAL PROPERTIES OF HYBRID FIBRE METAL LAMINATE

FAIZAL AZLI BIN HJ. JUMAAT

A report submitted
in fulfillment of the requirements for the degree of
Master of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

"I hereby, declared this report entitle of 'Mechanical properties investigation of reinforced light weight composite material' is the results of my own research except as cited in the references".

Signature	:	....
Author's Name	:	FAIZAL AZLI BIN HJ. JUMAAT
Date	:	10 JUNE 2016

APPROVAL

"I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality for the award of the Master of Mechanical Engineering (Automotive)".

Signature : ....
DR. SIVAKUMAR A/L DHAR MALINGAM
Pensyarah Kanan
Fakulti Kejuruteraan Mekanikal
Universiti Teknikal Malaysia Melaka

Supervisor : DR. SIVAKUMAR A/L DHAR MALINGAM

Date : 10 JUNE 2016

DEDICATION

To my beloved wife, Hasnah Bte. Ahmad and my lovely sons. Their sources of my inspiration and strength in pursuit of excellence. To my mother Patimah bte. Ngamin who always pray for us happiness. Thanks for all support and encouraged towards the end.

ABSTRACT

The main purpose of this research is to investigate the mechanical properties of hybrid fibre-metal-laminate (FML) with different orientations composites. The mechanical responses of FML composites reinforced by three layers of natural fibre or in combination with glass fibres were compared against those of different ply orientation and laminate layup. The tensile moduli of elasticity of the FML composites with various laminate layup were comparable to those of FML composites with different ply orientation. The ultimate tensile strengths and strain at failure of the FML composite with different ply orientation and laminate layup were also investigate. The mechanical response trends under impact of FML composites were compared against those of flatwise and edgewise of impact test. The FML laminates based on aluminium alloy 5052-0 connected with polypropylene adhesive film, polypropylene (PP), glass fibre (G) and kenaf fibre (K). The low velocity impact tests were performed by using impact pendulum tester according to ASTM E-23 standard and the tensile behaviour generally investigated using universal testing machine according to ASTM D 3039 standard. The effects of ply orientation (0°-90° / 45°-45°) and laminate layup (GGG/KKK/GKG/KGK) on the mechanical responses of the FMLs were also investigated. The morphological properties of FML composite samples were analysed through stereo microscope images and these clearly demonstrated the better interfacial adhesion between the woven kenaf fibre, woven glass fibre and the polypropylene matrix with different orientation. Result shows that, 50% reductions by weight for FML compared to monolithic aluminium, FML incorporating 45°/-45 woven orientations had inferior tensile properties in comparison to FML composites reinforced by 0°/90° woven orientation and FML layup with GKG shows the superior at both test methods.

ABSTRAK

Tujuan utama kajian ini adalah untuk mengkaji sifat-sifat mekanik bagi komposit gentian logam lamina (FML) yang mesra alam serta ringan. Tindak balas mekanikal komposit FML yabg diperkukuh oleh tiga lapisan serat semula jadi atau gabungan dengan gentian kaca dan dibandingkan berdasarkan orientasi lapis yang berbeza dan kombinasi lamina yang berbeza turut dikaji. Kekuatan tegangan muktamad, Young modulus dan ketegangan pada kegagalan komposit FML dengan orientasi lapis yang berbeza dan kombinasi lamina juga dikaji. Trend tindak balas mekanikal di bawah kesan menyerap tenaga hentakan bagi komposit FML telah dibandingkan secara terlentang dan sisi menggunakan ujian hentakan. Rekabentuk FML berdasarkan aloi aluminium 5052-0 yang dilekatkan menggunakan lapisan nipis polypropylene, polypropylene (PP), gentian kaca (G) dan serat kenaf (K). Ujian kesan halaju rendah telah dilakukan dengan menggunakan kesan bandul penguji mengikut standard ASTM E-23 dan tingkah laku tegangan umumnya dikaji dengan menggunakan mesin ujian universal mengikut standard ASTM D 3039. Kesan orientasi lapis (0°-90° / 45°-45°) dan kombinasi lamina (GGG / KKK / GKG / KGK) pada tindak balas mekanikal bagi FML juga dikaji. Ciri-ciri morfologi sampel komposit FML dianalisis melalui imej stereo mikroskop dan ini jelas menunjukkan lekatan antara permukaan yang lebih baik di antara gentian kenaf yang ditenun, gentian kaca tenunan dan matriks polypropylene dengan orientasi yang berbeza. Keputusan menunjukkan bahawa terdapat pengurangan berat sebanyak 50% antara FML berbanding aluminiun, FML yang menggunakan orientasi tenunan 45°/-45 mempunyai sifat tegangan lebih rendah berbanding dengan komposit FML diperkukuh oleh orientasi tenunan 0°/90° dan lamina FML dengan GKG menunjukkan sangat baik di kedua-dua kaedah ujian.

ACKNOWLEDGEMENT

Assalamualaikum W.B.T.

First of all, I would like to express my gratitude to Allah S.W.T., for giving me infinite grace, love and blessing, to enable me to pursue my ambition up to this point of my life. Hope him will accept me as His servant. Most special thanks to my beloved Muhammad S.A.W, peach and greeting upon him for his sacrifice.

This work is a synergistic of many minds. I am grateful for the inspiration and wisdom of many professionals and for the trans-generation sources and roots of this wisdom. Interdependent is higher value than independence.

Generously would like to take this opportunity to express my hear felt appreciation and thanks to respectable Dr. Sivakumar A/L Dhar Malingam for his continuing guidance, encouragement, supervision, advice and effort in completing this master programme.

Sincere thanks to all involve in this project direct or indirectly help me in conducting the experimental work. As for my family members, no amount of gratitude could reply your kindness of being there as well as the patience to put with my whim. My deepest gratitude in meant for all of you.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

Al	-	Aluminium
ARALL	-	Aramid Reinforce Aluminium Laminates
ASTM	-	American Society for Testing and Materials
CARALL	-	Carbon Reinforced Aluminium Laminate
CFRP	-	Carbon Fibre Reinforced Polymer
E	-	Young's Modulus
FML	-	Fibre Metal Laminates
FRP	-	Fibre Reinforced Polymer
G	-	Glass fibre
GFRP	-	Glass Fibre Reinforced Polymer
GLARE	-	Glass Reinforced Aluminium Laminate
Gpa	-	Giga pascal
ISO	-	International Organization for Standardization
K	-	Kenaf fibre
M	-	Mass (kg)
MPa	-	Mega pascal
PP	-	Polypropylene
T	-	Extraction temperature
UTM	-	Universal Testing Machine
UTS	-	Ultimate tensile strength
KPa	-	Kilo pascal
wt%	-	Weight percentage
ε_f	-	Strain at failure
%	-	Percentage
°C	-	Degree celsius

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The volume of thermoplastics used in the housing, automotive, packaging and other low-cost, high-volume applications is enormous. Recent interest in reducing the environmental impact of materials is leading to the development of newer materials or composites that can reduce the stress to the environment. In light of potential future petroleum shortages and pressures for decreasing the dependence on petroleum products, there is an increasing interest in maximizing the use of renewable materials. The need to develop light-weight but environmentally sustainable engineering materials has attracted research into natural fibre-reinforced composite (Shah, Porter, Vollrath, 2014).

Due to their low density and moderate mechanical properties, plant-derived fibres offer a plausible pathway towards new composite materials having mechanical property-to-weight relations on par with conventional composites incorporating man-made fibres such as glass aramid or carbon (Dittenber, 2012). When compared to synthetic fibres, plant fibre also possesses desirable physical characteristics including renewable and biodegradable credentials, environmentally-friendly processing and safe occupational handling (Joshi, 2004). The contemporary trend of replacing man-made fibres in FRP composites with plant-derived fibre can also be extended to Fibre Metal Laminates (FML). These composite materials possess the composites and have been demonstrated to have excellent damage tolerance characteristics (Sinmazcelik, Avcu, 2011).

Due to the relative low cost of aluminium alloys and glass fibres, Glass Laminate Aluminium Reinforced Epoxy (GLARE) has been the most studied and commercially ubiquitous FML composite (Botelho, Silva, 2006). However concerns with high processing costs and associated environmental issues as well as occupational handling of glass fibres have incentivised materials engineers to study the feasibility of FML reinforced with plant fibre. In an attempt to eliminate some of the environmentally-unattractive attributes of glass reinforcements, a handful of researchers (Kuan, Santulli, 2013) have investigated the mechanical behaviours of FML composites reinforced with plant fibres. Santulli and co-workers characterized the tensile and impact response of FML composite incorporating 2024-0 aluminium alloys and hemp or flax reinforced polypropylene laminates. While the mechanical responses of hemp reinforced FML were notably lower than those estimating using Rules-of-mixtures. The results confirmed the potential to adopt natural fibre-enhanced FML in load-bearing engineering applications. Vasumathi and Murali investigated the mechanical responses of FML composites incorporating jute fibre under bending, impact and tensile loading. Similar to research findings by Santulli and others, the observations also suggested the potential adoption of natural fibre in place of high-cost, environmentally-unfriendly and occupationally-unsafe synthetic fibres such as kevlar, aramid, carbon and glass. Wambua and others (Wambua, 2007) explored the anti ballistic benefits of bonding fibre polymer composite reinforced by hemp, flax, or jute onto steel plates. Sandwiching the fibre reinforced plastic laminates between 0.8 mm-thick steel plates increase the ballistic resistance of the laminates by 109%.

In the past two decades a number of researchers used natural fibres with a polymer matrix composite and this has received considerable attention both in the literature and the industry. Although synthetic fibres such as kevlar, aramid, glass, and carbon are extensively used for the reinforcement of plastics, these materials are expensive and are non-renewable resources (Salman, 2014). Many of the woven natural fabrics are rising as a viable option to glass fibre reinforced composites in industrial applications like packaging, paper making, and composite materials. The composite sandwiches consist of face-sheet (skin) and core material layup have various application areas including aeronautical, marine and transport industry. Beside the perfect flexural resistance and stiffness, high corrosion resistance, low thermal and acoustic conductivity are the major advantageous of these systems over the traditional materials. Although synthetic fibres such as kevlar, aramid, glass, and carbon are extensively used for the reinforcement of plastics, these materials are expensive and are non-renewable resources (Salman, 2014). Many of the woven natural fabrics are rising as a viable option to glass fibre reinforced composites in industrial applications like packaging, paper making, and composite materials.

One of the more popular natural fibres is kenaf fibre, which is an annual plant due to its rapid growth, and has an average yield of 1700 kg/ha (Khan, 2010). One of the celebrated constituents of natural fibre reinforced plastic composites in Malaysia is kenaf fibre. The research in kenaf plastic composite is growing tremendously along with the plastic industry's high demand for producing petroleum-based materials. The attractive features of kenaf fibres are the low cost, lightweight, renewability, biodegradability and high specific mechanical properties. Kenaf has a bast fibre which contains 75% cellulose and 15% lignin and offers the advantages of being biodegradable and environmentally safe. Among natural fibre composites, kenaf fibre reinforced composites have found potential applications for mobile phone shells consisting 15–20% kenaf fibres. Another example in the automobile industry is the Toyota RAUM, which is equipped with a spare tire cover made of kenaf fibre composites (Maya Jacob John et al., 2007).

1.2 PROBLEM STATEMENT

To date, limited research has been performed on the mechanical behaviours of FML composites integrating the advantageous mechanical properties of metallic alloys with the environmentally-friendly benefits of plant fibres. Therefore, in order to increase our understanding of the fundamental mechanisms driving damage in such FML composites when subjected to varied loading conditions, more research is required.

The increasing demands in automotive and aircraft industry for high performance, low cost and lightweight structures have stimulated a strong trend towards the development of FML. The worldwide automotive production rate is increasing and is estimated to reach 76 million cars annually by 2020. Limited petroleum resources will increase petroleum-based products' prices in the near future. It is estimated that a 25% reduction in car weight would be equivalent to saving 250 million barrels of crude oil (Lan R. Mair, 2000). Therefore it is possible that manufacturers will consider expanding the use of natural fibre in their new products.

This research will study the mechanical properties of hybrid fibre metal laminate under tensile loads and low velocity impact loads. For this, a FML made of the lightweight and anti corrosion Aluminium alloy 5052-0 with woven kenaf fibre and woven glass fibre reinforced polypropylene composite is manufactured for the testing. Epoxy is the most popular type of thermosetting resin used for fabricating FML composite, however due to the long processing time for curing and low fracture resistance, low cost thermoplastic (polypropylene) based composites are used as the matrix agent for the composite. Three layup configurations for the FML and two woven orientation (0°/90° and 45°/-45) were consider in this study.

1.3 AIM AND OBJECTIVES

The objectives of this research are:

a. To investigate the effect of woven fibre orientation and hybrid layup on tensile test.

b. To investigate the effect of woven fibre orientation and hybrid layup on impact test.

1.4 RESEARCH SCOPE

The scopes of the study are:

a. Fabricate the FML composites materials.

b. To conduct tensile test according to ASTM D3039.

c. To conduct impact test according to ASTM E23.

d. To study the failure.

CHAPTER 2

LITERATURE RIVIEW

2.1 INTRODUCTION

During the last three decades, there has been a search for lightweight materials that can replace the traditional aluminium alloys in aerospace structure. For an optimal structure design, a new material is needed which combines high strength, low density high elasticity modulus with improve toughness, corrosion resistance and fatigue properties. Fibre reinforced composites materials almost cover all these demands. Fibre metal laminates (FML) take advantages of metal and fibre reinforced composites, proving superior mechanical properties to the conventional lamina consisting only of fibre-reinforced lamina or monolithic aluminium alloys. Due to their advantages, FMLs are finding great use in aerospace and vehicle. A number of companies have interest in substitute the traditional aluminium components by FML composite. Fibre metal laminates have been successfully introduced into the Airbus A380 (Beumler, 2006).

2.2 MATERIAL

FML composites composed of two thin aluminium layers connected with fibre reinforce polymer composite. It consist metallic sheets and fibre as composite layers. The concept usually applied to aluminium with aramid, carbon or glass fibre, but also can be applied to other constituents. Figure 2.1 gives a classification of FML based on metal plies.