



Faculty of Manufacturing Engineering

**DEVELOPMENT OF KENAF POLYMER COMPOSITE SANDWICH
STRUCTURE**

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Master of Science in Manufacturing Engineering

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STRUCTURE**

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**A thesis submitted
in fulfilment of the requirements for the degree of Master of Science
in Manufacturing Engineering**

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

DECLARATION

I declare that this thesis entitled “Development of Kenaf Polymer Composite Sandwich Structure” 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 thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature :.....

Supervisor Name :.....

Date :.....

DEDICATION

For my beloved family:

HUSBAND

FATHER

MOTHER

SIBLINGS

For my adored supervisor and co-supervisor:

Dr. Taufik

Professor Madya Engr. Dr. Hambali bin Arep@Ariff

ABSTRACT

This research presents the development of kenaf polymer composite sandwich structure. The aim of this research is to propose natural fibre composites to be introduced in metal matrix composites material for further manufacturing processes. The core natural fibre material used is kenaf fibre while polyester and polypropylene act as matrix materials. LM6 material was selected as metal matrix composites and used as the skin of sandwich layers for simulation study. Two types of composite processes had been used in this research, hand lay-up process for application of polyester and hot moulding process for polypropylene application. These two types of laminate composite have been tested to analyse the mechanical properties and thermal properties. Based on the testing results, kenaf-polyester composite had been chosen as the proposed material to be applied to the sandwich model. The natural fibre composites were tested by mechanical and thermal testing procedures to meet the ASTM requirements. There were 5 types of ASTM standard has been used in this research such as ASTM D3039, ASTM D638-99, ASTM D7624, ASTM D790 and ASTM E794-01. Tensile test, flexural test, and thermal test had been used in this research. Five specimens were prepared for tensile test and flexural test, followed by one specimen for each laminate composite in thermal test. Thermal test procedure had been prepared by using DSC (Differential Scanning Calorimetric) method. The results showed the polyester was the optimum material to be used as the matrix material for laminate composite due to the high tensile and flexural strength as well as high in the value of maximum force. The DSC test result shows the greater melting temperature in polyester as compared to polypropylene. Furthermore, the LM6 model and sandwich model were designed by using SolidWorks simulation to determine the stress distribution, displacement distribution and factor of safety. As a result, kenaf-fibre polyester composite as core layer in sandwich model of LM6 was potential to be applied for engineering application.

ABSTRAK

Kajian ini membentangkan pembangunan struktur sandwich komposit polimer kenaf. Tujuan kajian ini adalah untuk mencadangkan komposit serat semulajadi yang akan diperkenalkan dalam bahan komposit logam matriks untuk proses pembuatan yang mendatang. Bahan serat semulajadi teras yang digunakan adalah gentian kenaf manakala polyester dan polipropilena bertindak sebagai bahan matriks. Bahan LM6 telah dipilih sebagai komposit matriks logam dan digunakan sebagai kulit lapisan sandwich untuk kajian simulasi. Dua jenis proses komposit telah digunakan dalam penyelidikan ini iaitu tangan proses hand lay-up untuk digunakan daripada bahan polyester dan proses pengacuan panas untuk digunakan oleh polipropilena. Kedua-dua jenis lamina komposit telah diuji untuk menganalisis sifat-sifat mekanikal dan sifat haba. Berdasarkan kepada keputusan ujian, kenaf-poliester komposit telah dipilih sebagai bahan yang dicadangkan untuk digunakan bagi model sandwic. Komposit serat semulajadi telah diuji oleh prosedur ujian mekanikal dan haba untuk memenuhi keperluan ASTM. Terdapat 5 jenis ASTM standard telah digunakan dalam kajian ini seperti ASTM D3039, ASTM D638-99, ASTM D7624, ASTM D790 dan ASTM E794-01. Ujian tegangan, ujian lenturan, dan ujian terma telah digunakan dalam kajian ini. Lima specimen disediakan untuk ujian tegangan dan ujian lenturan, diikuti dengan satu specimen untuk setiap lamina komposit dalam ujian terma. Prosedur ujian Thermal telah disediakan dengan menggunakan kaedah DSC (Pengimbasan Perbezaan kalorimetri). Keputusan menunjukkan polyester adalah bahan yang optimum untuk digunakan sebagai bahan matriks untuk lamina komposit kerana kekuatan tegangan yang tinggi dan lenturan serta tinggi dalam nilai daya maksimum. Keputusan ujian DSC menunjukkan suhu lebur yang lebih besar dalam polyester berbanding dengan polipropilena. Tambahan pula, model sandwich dan model LM6 telah direka dengan menggunakan SolidWorks simulasi untuk menentukan taburan tekanan, pengedaran anjakan dan factor keselamatan. Hasilnya, kenaf serat komposit polyester sebagai lapisan teras dalam model sandwich LM6 berpotensi untuk digunakan bagi aplikasi kejuruteraan.

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LIST OF SYMBOLS

%	-	percent
MPa	-	Mega Pascal
GPa	-	Giga Pascal
T _g	-	Glass transition temperature
T _m	-	Melting temperature
T _{use}	-	Temperature which is used
°C	-	Degree Celsius
Wt%	-	Weight percentage
~	-	Approximate
g	-	Gram
μm	-	Micrometer
cm	-	Centimetre
mm	-	millimetre
MJ	-	Mega Joule
s	-	second
kg	-	kilogram
kN	-	Kilo newton
min	-	minute

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LIST OF ABBREVIATIONS

DfS	-	Design for Sustainability
OPEFB	-	Oil palm empty fruit bunch
PMC	-	Polymer matrix composite
ASTM	-	American standard testing method
MMC	-	Metal matrix composite
CMC	-	Ceramic matrix composite
UP	-	Unsaturated polyester
UPR	-	Unsaturated polyester resin
PP	-	Polypropylene
DSC	-	Differential scanning calorimetry
TMA	-	Thermomechanical analysis
DMA	-	Dynamic mechanical analysis
DEA	-	Dielectric analysis
PEEK	-	Polyether ether ketone
FRP	-	Fibre reinforced composite
CAD	-	Computer aided design and drafting
CADD	-	Computer aided design
3D	-	3 dimensional
2D	-	2 dimensional
FEA	-	Finite element analysis

MEKP	-	Methyl ethyl ketone peroxide
GMT	-	Glass mat thermoplastic
AE	-	Acoustic emission
Si	-	silicon
Al	-	aluminium
HV	-	Hardness Vickers
UTM	-	Universal testing machine

LIST OF PUBLICATIONS

Nurul, F.A.M., Taufik, R.S., and Mohammad, H.A.K., 2014. Feasibility Study of Casted Natural Fibre-LM6 Composites for Engineering Application. *Advanced Materials Research*, 903, pp. 67-72.

(International Manufacturing Engineering Conference [IMEC 2013])

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(International Conference on Design and Concurrent Engineering [iDECON 2014])

CHAPTER 1

INTRODUCTION

1.1 Background

The development of natural fibre composites have been attracting researchers to offer more attention due to their effective cost, reasonably fine mechanical properties, non-abrasive and biodegradable types (Ku et al., 2011). Daniel and Suong (2003) stated composite material is different from common heterogeneous materials. According to Kaw (2005), composite is a structural material that consists of two or more joint constituents. They are combined each other at a macroscopic level and are soluble. One constituent is known as filler and the other one is known as matrix. Armstrong et al. (2005) highlighted that composites are combinations of materials which differing in composition or form where the entity constituent retain their separate identities and do not dissolve or merge together. Application of composite materials represented as 70 % of market value, 23 % automotive, 21 % public work, 23 % building, 17 % aeronautics and 11 % sport as studied by Shakila (2006).

Natural fibre composite is widely discussed in various manufacturing industries due to their relatively low material cost and potential to reduce the overall production cost, without compromising the design requirements, and customer satisfaction. There are various applications in order to increase the strength ratio and flexibility in designing of products. Natural fibre composite is one of the preferred approaches. These natural fibres

have various properties which make the natural fibre an attractive alternative material. Most of researchers have been exploring on the potential of high specific properties and advantages of natural fibre such as its quality in stiffness (Sherman, 1999), impact resistance (Sydenstricker et al., 2000), flexibility (Manikandan et al., 1996), modulus elasticity (Eichhorn et al., 2001), and renewable capability. Natural fibres can be classified into three categories which are bast, seed and leaf (Sgriecia et al., 2008). The design of natural fibre composites involves fabricating the physical specimens for analysis on the microstructures of natural fibre product and study on their mechanical properties. Exploration of the use of natural fibre composite materials and what type of natural fibre composite needs to be further investigated particularly in designing of production tooling.

The application of design for sustainability faces various challenges in manufacturing. The most outstanding challenges which to be resolved is to contribute to the alteration in the direction of a sustainable society by integrating some aspect such as economic, social, ecological and institutional by contribution opportunities to express one's own identity further than consuming standardized mass products. Several design methodology have been recently proposed in order to study the feasibility of using angles of design, sustainability science and sustainable consumption analysis, developing tools and rules to support Design for Sustainability (DfS) (Joachim et al., 2010). Besides that, the design methodology systems analysis perspective is to extend the conventional process design structure to green process design, green energy and industrial ecology leading to sustainability (Urmila and Yogendra, 2010). The green process design starts with the design decisions by considering chemical and materials variety stages at one end which planning and managing decisions at the other end. Nevertheless, uncertainties and multiple and conflicting objectives are inherent in such a design process. Uncertainties enhance further in industrial natural science.