KENAF CORE SANDWICH STRUCTURE COMPOSITES TOUGHENED WITH MODIFIED EPOXY

BY

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A thesis submitted in fulfilment of the requirement for the degree of Master of Science
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ABSTRACT

This study was undertaken to enhance the properties of kenaf core epoxy matrix in sandwich structure, in addition to improve on mechanical, thermal and morphological properties. Sandwich panel was prepared by hand lay-up method. Sandwich panel were prepared in the ratio of 30wt%:70wt% from kenaf fiber and epoxy. The kenaf fiber was treated with natrium hydroxide (NaOH) to improve the interaction between fiber-matrix. Liquid natural rubber (LNR) was used as impact modifier and toughened agent in order to modify the epoxy matrix within 0wt%-5wt% of LNR. Mechanical test such as flexural, drop impact and tensile test were performed to investigate the optimum system of kenaf-core sandwich panel. All tests have been carried out according to the ASTM 365, C297, C393, and D1736. Each final data point is an average value that has been obtained based on a statistical sampling of six specimens. The main element of core structure is kenaf and the skin used in this study is aluminium type 1100. According to compression, flatwise tensile, three point bending and drop impact tests, 3wt% of LNR content exhibit as an excellent impact modifier, in modifying the mechanical properties due to rubber toughening. The mechanical properties of sandwich panel showed an increasing trend up from 0 wt% to 3 wt% of LNR content with optimum tensile strength 37.62 MPa and 21.6% increase in Young's modulus. The addition of 5wt% was substantially interrupted the system. These findings were also supported by scanning electron micrograph (SEM). SEM micrograph further showed that LNR act as impact modifier and cushioning by absorbing the energy and transfer within the matrix, preventing the crack from continuing cracking on the sandwich panel. TGA results showed that with the presence of LNR could improve the thermal stability of sandwich panel with high degradation temperature. Thus, all sandwich panels contain LNR show higher thermal stability compared to the kenaf core with neat epoxy. Water absorption was inversely proportional with the increasing of LNR composition into kenaf core epoxy matrix which was two times lower than kenaf core epoxy composite without rubber. All the results showed that the sandwich structure in the presence of LNR greatly increased the performance of sandwich structure when rubbery particles dispersed throughout the thermoset matrix.

ملخص البحث

هذه الدراسة حاولت على تعزيز خصائص التيل مصفوفة الايبوكسي الأساسية في هيكل ساندويتش، بالإضافة إلى تحسين الخواص الميكانيكية والحرارية والمورفولوجية. و لقد تمّ إعداد لوحة ساندويتش على طريقة وضع المتابعة مع الخصائصها الأمثل، و ذلك وضعها في ثلاثين بالنسبة إلى سبعين من الألياف التيل والايبوكسي. و قد اختُبِرت فى هذه الطريقة الألياف التيل مع هيدروكسيد الصوديوم (NaOH) لتحسين التفاعل بين الألياف المصفوفة بإستخدام المطاط الطبيعي السائل (LNR), من أجل تأثير و تعديل مصفوفة الايبوكسي مابين صفر بالمائة إلى خمس بالمائة على وزن المطاط الطبيعي السائل. فأجريت الاختبار الميكانيكي مثل العاطفة، وانخفاض تأثير الشد واختبار في النظام الأمثل لتحقيق لوحة ساندويتش التيل النواة. وقد أجريت جميع الاختبارات وفقًا لجنس STM 365، C297، C393 و D1736. و كل نقطة البيانات النهائية هو متوسط القيمة التي تمّ الحصول عليها على أساس أخذ العينات الإحصائيّة من أربع عينات. فالعنصر الرئيسي للبنية الأساسية هي التيل المصفوف , أما الجلد المستخدم في هذه الدراسة هو من الألومنيوم نوع 1100. ووفقًا للضغط و قوّة الشدّ ثلاث نقاط الانحناء وإسقاط الاختبارات الأثر، ثلاث بالمائة من المطاط الطبيعي السائل (LNR) و وزن المعرض المحتويات باعتبارها معدل تأثير ممتازة . و في تعديل الميكانيكية خصائص أيضًا, وذالك بسبب تشديد المطاط المذكور. و أظهرت الخواص الميكانيكية للوحة ساندويتش اتجاها متزايدا يصل من صفر إلى ثلاث بالمائة من وزن المحتوى LNR مع الأمثل قوّة الشد 37.62 ميجا باسكال وزيادة 21.6 بالمائة في معامل يونغ . و في إضافة الكثير من LNR أكثر من خمس بالمائة تكون مشكلة كبيرة في النظام . ودعمت هذه النتائج أيضا عن طريق مسح صورة مجهرية الإلكترون (SEM) , وأظهرت فيها أن شطيرة التيل الأساسية مصفوفة الايبوكسي في وجود رابطة اندية الدوري الفرنسي ازداد التفاعل بين حشو واجهة مع هيكل المتفرقة من المطاط الجسيمات وأسفر عن خصائص صلابة جيدة. كانت المعلمة المعالجة المثلى المستخدمة في التحليل الحراري الوزني (TGA) في 27°C إلى 1000°C لكل دقيقة بمعدل تسخين . وأظهرت النتائج فى هذه الدراسة أن التحليل الحراري الوزني مع وجود رابطة اندية الدوري الفرنسي يمكن أن تحسن الاستقرار الحراري للوحة ساندويتش مع درجة حرارة عالية التدهور. وبالتالي، كل لوحة شطيرة تحتوي على المعرض المطاط الطبيعي السائل (LNR) إستقرّت على أعلى الحرارية مقارنة الأساسية التيل مع الايبوكسي الأنيقة. و كان امتصاص الماء يتناسب عكسيا مع زيادة تكوين رابطة اندية الدوري الفرنسي في التيل مصفوفة الايبوكسي الذي كان أقل مرّتين من التيل الأساسية الايبوكسي مركب دون المطاط. وأظهرت النتائج كذالك أن كلّ هيكل شطيرة في وجود رابطة اندية الدوري الفرنسي زيادة كبيرة في أداء هيكل ساندويتش عندما وُجِدت جزيئات مطاطي المتناثرة في أنحاء التيل المصفوفة بالحرارة.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Materials Engineering).

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted for any other degrees at IIUM or other institutions.

Norhasnidawani Binti Johari

Signature ………………………………. Date …………………………

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ACKOWLEDGEMENTS

بِسْمِ اللهِ الرَّحْمَنِ الرَّحِيْمِ

"IN THE NAME OF ALLAH, MOST GRACIOUS, MOST MERCIFUL"

Alhamdulillah, praise be to Allah, The Almighty for His kindness and blessing that I have successfully finished the project on kenaf core sandwich structure composites toughened with modified epoxy, it is my pleasure to acknowledge the generous assistance I received from many people during the preparation of this project. First and foremost, to my supervisor Dr Noor Azlina Hassan, for her knowledge, patience, encouragement, and advice were essential to my success here. I appreciate all the confidence and respect she had for my work. I would like to express my deepest appreciation and thanks to her for her continuous comments and suggestions for improvement and assistance throughout the period of this project development. She has provided me with tremendous knowledge and experience throughout the completion of this research. I am very grateful for her encouragement and patience in supervising me. InsyaAllah, ALLAH (s.w.a.) will return you with Prosperity, Happiness, Wealth and Blessing in this Life and in the Hereafter.

My gratitude also goes to my co-supervisors, Assoc Prof Dr. Zuraida Ahmad**.** I really do appreciate her assistance, especially in the development stages of my research and for their kind support and meaningful contributions. Much of my experimental work would not have been smoothly completed without the assistance of all research members as well as the Department of Manufacturing and Materials Engineering with all our technical staff especially Br. Hairi, Br. Farid, Br. Hafiz and Br. Hamri. All of you are excellent at what you do, and are extremely patient and helpful. Furthermore, I would like to express my heartiest gratitude to my colleague members, Faizah Fuad, Izzati Zulkifli and Athiya Sabaruddin for their cooperation in this project. My thanks go to the Kulliyyah of Engineering of IIUM for providing me support and also engaged me as a Tutor in last period of my research. Also very special thanks to my dearest parents, who have made most of all this possible.

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LIST OF ABBREVIATIONS

Al	Aluminum
ASTM	American Society for Testing Materials
ISO	International Organization for Standardization
CTRM	Composite Technology Research Malaysia
ACM	Asian Composites Manufacturing Sdn. Bhd
PS	Polystyrene
PU	Polyurethene
Acrylic	Polymethylmethacrylamide
PEI	Polyetherimide
SAN	Styreneacrylonitrile
SEM	Scanning Electron Microscopy
KF	Kenaf Fiber
KFI	Kenaf Natural Fibre Industrie
kN	Kilo-newton
LC	Laminated Composites
mm	Millimetre
MPa	Mega-Pascal
TGA	Thermogravimetry Analysis
Bhd	Berhad
BS.	British Standard
Sdn.	Sendirian
MSDS	Material Standard Data Sheet
LNR	Liquid Natural Rubber

LIST OF SYMBOLS

Tc	Crystallization temperature
Tf	Final decomposition temperature
Tg	Glass transition temperature
Tβ	β-transition temperature
Ti	Initial decomposition temperature
Tm	Melting temperature
μm	Micrometer
Vf	Volume fraction
V%	Volume percent
wt%	Weight percent
^{o}C	Degree Celsius
ρ	Density
g	gram
g/cm3	gram per cubic centimeter
GPa	Giga-Pascal
π	pie
σ	Remotely applied stress
τ	Interfacial shear stress constantly along the fiber length
D	Density
F	Force
P	Load applied
R_c	Resin in composite, weight %
r	Reinforcement in composite, weight %
T	Theoretical density
v	Volume
v_c	Volume of composite
V_f	Fibre volume fraction, %
V_m	Matrix volume fraction, %
v_m	Volume of matrix
V_v	Void fraction, %
w	Fibre weight fraction
w_m	Matrix weight fraction
E	Young Modulus of elasticity
N	Newton
A	cross-sectional area of the sample
ε	Strain value
ΔL	Increase in the specimen length between the gauge mark
L	Span length of the specimen
b	Width of the specimen
h	Thickness of the specimen
E_f	Modulus of fiber

CHAPTER 1

INTRODUCTION

1.1 CURRENT AND FUTURE PERSPECTIVES: AN OVERVIEW

The contents and the sequences of this chapter have been developed with the principle objectives of (1) to develop an understanding the structure of sandwich in composite technology from kenaf fiber and the modification of epoxy in order to overcome the limitations; (2) to provide the necessary understanding of the objective, scope, and methodology of the current research; (3) to characterize the mechanical, thermal and morphological properties of the developed composites; and (4) to construct an overview of the benefits which could be derived from research. The study will focus on kenaf Core Sandwich Structure composite toughened with modified epoxy.

Berthelot et al. (2008) reported that a composite means more than one material combined in a certain composition in order to produce useful product for engineering application by optimizing their functionality while minimizing the effect of their deficiencies. Composite materials offer high strength, stiffness, corrosion resistance, wear resistance, attractiveness, low weight and long fatigue life. Composite materials must satisfy manufacturability requirements as well as their final properties, resulting from the combination of two or more materials must be better than conventional metals (Chawla, 1998). Composite can also be defined as combining the good properties of reinforcing fiber with a matrix(Schwartz, 1997). Israelities used straw to strengthen mud bricks and Egyptians used plywood in order to achieve high strength and resistance to thermal expansion in construction (Seiglie, 1997). Three common types of composites are fibrous composite, laminated structure, and matrix.

“Weight is an enemy” is the most important principle for airplane designer. The heavier an aircraft, the shorter flight distance. This is because more fuel must be burnt for loaded carriage. For example, Air Asia-X commercial flight has to transit at the Gulf countries due to small fuel tank capacity which is not enough being able to support direct flights from Kuala Lumpur to London/Manchester. Likewise, Airbus A380 has to deal with 4 ton of extra load (design structure) in its commercial flights (Mohd, 2007). Hence, researchers resort to composite materials with high strength to weight ratio, stiffness to weight ratio, corrosion, fracture resistance, and cost effectiveness in order to make the structural components effective for many applications in the aircraft industry.

Recent Boeing development introduced a new Boeing 787 Dreamliner aircraft which has at least 80% composite materials in its construction. This helped to reduce a large portion of the weight. The fuel consumption, as a result was also reduced by up to 20%. It was considered as superefficient airplane. To counter this, Airbus had also introduced the Airbus A350 XWB (Extra Wide Body) whose structure was composed up to 72% of composite material. Most equipment was made from plastic materials resulting by a passenger capacity of up to 350. Mohd (2007) reported that Malaysia Airline System announced in their 2004/05 financial report that they were spending more than RM 3 billion in fuel alone. Thus, 20% reduction in fuel consumption could save at least RM 600 million.

Kailan-1 was recorded in the Malaysian Books of Record for its mission to fly across East Asia within seven days using a Malaysian home-made light aircraft. The aircraft was developed and produced by Composite Technology Research Malaysia (CTRM) in 2004. CTRM started operation about 15 years ago with the company building single-engine propeller planes for the civilian and military markets. CTRM has been one of the most successful composite manufacturers in Malaysia, and have produces aircraft components for Airbus A319, A320, A331, Laincair Columbia 300, and assemblies for the Eagle 150B aircraft. Some parts of A320 airplane components that were produced by CTRM as in Figure 1.1.

Among the composite components that CTRM had been supplying to Airbus for its A300 and A320 series aircrafts are: the wing panels, spoilers, ailerons, moveable fairings and nacelles. Airbus A380 was super jumbo jets producing by CTRM. CTRM Aero-Composite Sdn. Bhd. (CTRM AC), a unit of CTRM, has currently secured a contract worth over RM120 million for supplying high-tech components to Goodrich Aero structure Group for the V2500 aero engine. TheV2500 engine has been used in Airbus A320 series (Mohd, 2007)

Figure 1.1: Components made from composite materials for Airbus A320 manufactured (CTRM 2006)

Mohd (2007) also reported that, Asian Composites Manufacturing Sdn. Bhd. (ACM), a strategic alliance between Sime Darby Bhd., Naluri Bhd., The Boeing

Company and Hexcel Corporation, and located in Bukit Kayu Hitam produces advanced composite panels for wings of the B737, B747, B757, B767 and B777 aircraft in the Boeing family. This company started production in 2001.On the other hand, Dian Kreatif Sdn. Bhd. (a Malaysian company) has produced yachts of various size especially for international races. They have recently penetrated the markets in Hong Kong, Australia, France, United States and a few other European countries. Dian Kreatif had previously made domes from composite materials. Among the domes which have been built are the dome on the Prime Minister’s official residence in Putrajaya, Putrajaya Mosque, Federal Territory Mosque and Al-Bukhary Mosque in Alor Setar, Kedah. The company’s domes were also used for the Conference Palace Hotel Complex, now under construction in Abu Dhabi.

1.1.1 Green Structural Technology

Natural fiber was introduced as reinforcement in polymers for making composites in the past. Common and naturally fiber is kenaf. It is extracted from a tropical plant grown for its fibers. Recently, there is interest in investigating the applicability of kenaf products in the polymer processing industry because it is low cost and a renewable agricultural product. Moreover, the reason that kenaf is so special is that it is biodegradable. In today’s world, where huge amounts of chemical wastes are created routinely, an environmentally friendly product is very attractive. Therefore, nowadays natural fibers are used in fabricating automotive components, soundproofing systems, thermal insulations, and green buildings (Gay, 2003). Thus, this research deals with a similar topic: the development of kenaf core sandwich structure composite toughened with modified epoxy.

1.1.2 Sandwich Panel Technology

The selection of proper materials and designs becomes important as Malaysia strives to implement green building technologies. Thus, the material's performance and failure become critical issues. Sandwich composite can reduce the amount of material used, thereby producing lightweight materials. Moreover, nowadays the applications of sandwich composites appear to be very prevalent. With its outstanding mechanical behavior, sandwich panel is widely used in a variety of aerospace, automotive, and building construction applications. Besides, it is also being used in marine ships such as in bulkheads, ship's body, and partitions in the ship. For instance, the U.S Navy is using honeycombed sandwich bulkheads in order to reduce the weight of its ship. Along with marine and navy ships, other applications of sandwich composites include sailboats, racing boats, and auto racing cars. Furthermore, sandwich structure also has excellent thermal properties which make it ideal for use in heat in insulated barriers(Gay et al., 2003).

Figure 1.2 shows sandwich construction in engineering application made from different types of raw materials. In aircraft application, the most expensive material used is the Aramid fiber. Furthermore, structural performance can be defined as the performance of sandwich panel structure. It is cover the performance of every single layer in sandwich structure.

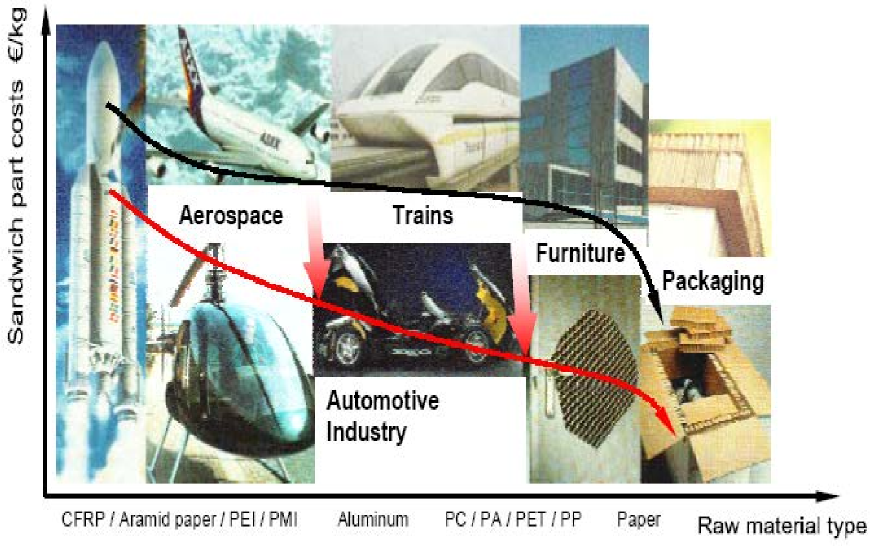

Figure 1.2: Sandwich construction in engineering applications (Gay et al., 2003)

Sandwich panel can be defined as a sandwich structured composite that consists of stiff skins and a thick core (Cesim & Cenk, 2010).Adhesive are placed between the skin and the core in a sandwich structure. The most pressing concerns in sandwich structure design and fabrication are weight and performance of the constituent materials. The thickness can be varied depending on the type of materials used in fabricating the sandwich structure (Antoine et al., 2010). In general, the skin material can be metallic, wood, glass or composite laminates. This study, used composites laminates as shown in Figure 1.3.

It has been found that sandwich constructions give higher strength, better fatigue resistance properties and more effective thermal and acoustical insulation properties compared to conventional materials. However, an essential requirement in sandwich construction is that the skin must be able to absorb the stress and force acting on it.

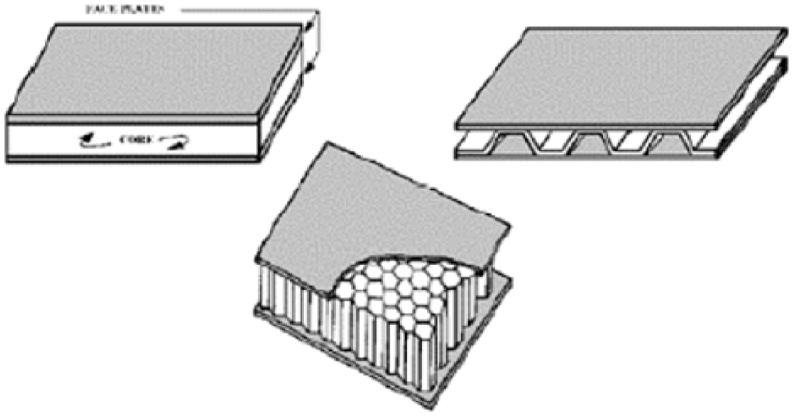

Figure 1.3: Sandwich construction (Cesim & Cenk, 2010)

1.2 PROBLEM STATEMENT

Sandwich panels face delaminating problems which can lead to overall failure of its functionality. Sandwich structures are commonly subjected to a variety of loading conditions such as bending, tension, compression, impact and fatigue. Thus, it is important to develop sandwich structures by improving and optimizing their mechanical integrity for a wider range of applications. The adhesives used in the matrix also play an important role in determining the performance of sandwich structures. The ductility of the sandwich structure can be improved by modifying its core structure with toughening agent like rubber particle.

Today, the applications of sandwich structure encompass many aspects of the society such as construction of buildings, and cars. Nowadays, people are more concerned about the nature of the materials used in engineering applications. They demand that the materials must be ecologically and is environmentally friendly, and not cause health problems. Due to the composite's light weight, easy processability, and minimal labor costs, the sandwich structure is an economically viable alternative to conventional materials. Moreover, the cost of the material has to be low without reducing the mechanical performance of the product.

The long term performance of sandwich structure is affected not only by the properties of the constituent materials but also by the whole fabrication process; the latter has been difficult to control. So, the material selection, surface treatment of the fiber and the ratio of adhesive must be clear. Therefore, in this research a sandwich structure was been developed using eco-core, which is kenaf fiber reinforced epoxy matrix with an aluminium skin. The main concern of this research was the chemical properties of the core and the adhesive. These modifications were made to the epoxy matrix with the incorporation of liquid natural rubber (LNR) and the properties of enhanced epoxy were compared with those of the existing epoxy. In addition, the sandwich panels were verified at different percent of LNR addition in order to increase the properties of the modified epoxy.

1.3 RESEARCH OBJECTIVES

The main objective is to fabricate a kenaf core sandwich structure composite toughened with modified epoxy. In order to achieve this main objective, the following secondary objectives must be fulfilled.

1. To study fiber loading in epoxy matrix on kenaf sandwich structure.
2. To characterize the mechanical, thermal and morphological properties of the kenaf core sandwich structure composites.
3. To investigate the performance of kenaf core sandwich structure composite in the present of liquid natural rubber (LNR)as impact modifier.

1.4 RESEARCH SCOPE

There are some important properties which must be considered in experiment. One of them is density. Density is important to reduce the weight of the material. Other properties such as shear modulus and shear strength are also important as the core carries the bulk of the shear loads. Compression stiffness and strength are important because the force is applied perpendicular to the skin's face. The selection of fiber, matrix and skin plays an important role in optimization of the performance of the sandwich structure. In order to achieve the objectives above, sandwich structure is fabricate by hand lay-up method in the present of 0wt%-5wt% of LNR and the scopes of the research are as follows:

i) Study the different composition of kenaf fiber between 10wt%-30wt% of fiber

ii) Study the effect of treated kenaf fiber after immersion in alkaline solution on SEM

iii) Study the effect of modification of epoxy incorporation of LNR

1.5 BENEFITS OF THE RESEARCH

The research upshot from this study and investigation include the following:

i. Development of kenaf core metal matrix composite sandwich structure.

ii. Development of new and modified matrix for the composite sandwich structure.

The results of this research work could benefit the composite industries, and research institutions working on advanced fiber composite materials. At the national level, this research would also: