UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION ON MECHANICAL PROPERTIES OF RECLAIMED NONWOVEN CARBON FIBER COMPOSITE FOR SECONDARY APPLICATION

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

HAWA BINTI AHMAD FUZI

B051510209

960917-08-5412

ꓸCULTY OF MANUFACTURING ENGINEERING

2019

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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Sesi Pengajian: **2018/2019 Semester 2**

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CHT JERING, TAIPING, PERAK.

Tarikh: 26/06/2019

Cop Rasmi: DR. ZURINA BINTI SHAMSUDIN
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

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Tandatangan Pelajar:

Nama Pelajar: HAWA BINTI AHMAD FUZI

No Matriks: B051510209

Tarikh: 26/6/2019

Tandatangan Penyelia:

Cop Rasmi: DR. ZURINA BINTI SHAMSUDIN
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

Nama Penyelia:

Jawatan:

Tarikh: 26/06/2019

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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Tel: +606 – 270 2571 / Faks: +606 – 270 1047

Rujukan Kami (Our Ref) : UTeM.
Rujukan Tuan (Your Ref) :

Ketua Pustakawan
Perpustakaan Laman Hikmah,
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya, 76100 Durian Tunggal
Melaka.

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NAMA: HAWA BINTI AHMAD FUZI

Sukacita dimaklumkan bahawa Laporan PSM yang tersebut di atas bertajuk "*Investigation on Mechanical Properties of Reclaimed Nonwoven Carbon Fiber Composite for Secondary Application*" mohon dikelaskan sebagai ~~*SULIT /~~ TERHAD untuk tempoh LIMA tahun dari tarikh surat ini.

2. Hal ini adalah kerana ianya merupakan projek yang ditaja sepenuhnya oleh syarikat luar (CTRM Aero Composite.) dan hasil kajiannya adalah sulit.

Sekian dimaklumkan. Terima kasih.

Yang benar,

DR. ZURINA BINTI SHAMSUDIN
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

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DECLARATION

I hereby, declared this report entitled "Investigation on Mechanical Properties of Reclaimed Nonwoven Carbon Fiber Composites for Secondary Application" is the results of my own research except as cited in reference.

Signature : ....

Author's Name : HAWA BINTI AHMAD FUZI

Date : 26 June 2019

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering.

The members of the supervisory committee are as follow:

....

(Dr Zurina Binti Shamsudin)

DR. ZURINA BINTI SHAMSUDIN
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

ABSTRACT

Reclaimed carbon fiber is crucial in reducing waste from the increasing use of composites reinforced with carbon fiber in industry. Compared to continuous virgin carbon fiber, reclaimed carbon fibers are usually short and discontinuous. In this project, the nonwovens mat produced and processed using wet-laid process adapted from the papermaking technique. After the reclaimed nonwoven carbon fiber laminates fabricated, the physical properties of the mats measured and observed. A reclaimed carbon fiber mat was processed to fabricate the reclaimed carbon fiber reinforced polymer composite using vacuum bagging that was attached with resin transfer molding (RTM). The control sample, virgin carbon fiber and reclaimed carbon fibers were performed flexural testing and impact testing. The micrographs of the fracture surfaces of the composite specimens submitted for flexural and impact testing were performed using scanning electron microscope (SEM). The results obtained from rCFRP for 2 plies and 3 plies of rCF mat shows that composite with higher rCF content has higher flexural strength and more impact force absorption. The nonwoven mat rCFRP with higher rCF content has a higher toughness of the fracture which mainly controls the number of plies mat. The morphological obtained from the failure mode showed debonding and pulling out mode.

ABSTRAK

Gentian karbon yang ditakrif adalah penting dalam mengurangkan sisa daripada peningkatan penggunaan komposit yang diperkuat dengan gentian karbon dalam industri. Berbanding dengan gentian karbon dara yang berterusan, gentian karbon yang direkabentuk biasanya pendek dan tidak berterusan. Dalam projek ini, tikar bukan tenunan dihasilkan dan diproses menggunakan proses basah yang disesuaikan dengan teknik pembuatan kertas. Selepas lamina gentian karbon yang tidak ditenun dihasilkan, sifat fizikal tikar diukur dan diperhatikan. Suatu tikar gentian karbon yang telah direkabentuk telah diproses untuk mengarang komposit polimer bertetulang gentian karbon yang direkabentuk menggunakan pembungkus vakum yang dilampirkan dengan acuan pemindahan resin (RTM). Sampel kawalan, gentian karbon dara dan rekabentuk telah dilakukan ujian lenturan dan ujian kesan. Mikrograf permukaan patah dari spesimen komposit yang dihantar untuk ujian lenturan dan kesan dilakukan dengan menggunakan mikroskop elektron scanning (SEM). Keputusan yang diperoleh dari rCFRP untuk 2 keping dan 3 keping rCF menunjukkan bahawa komposit dengan kandungan rCF yang lebih tinggi mempunyai kekuatan lenturan yang lebih tinggi dan lebih banyak penyerapan daya impak. rCFRP tikar bukan tenunan dengan kandungan rCF yang lebih tinggi mempunyai ketangguhan yang lebih tinggi dari patah yang terutamanya mengawal bilangan kepingan tikar. Morfologi yang diperolehi dari mod kegagalan menunjukkan mod pemisahan dan menarik keluar.

DEDICATION

All the hard work is only for you:
my beloved father, Ahmad Fuzi bin Abdul Hamid
my appreciated mother, Nurul Akmar binti Hj Md Nasir
my adored brothers and sister,
Adam, Alya and Azim
for giving me moral support, money, cooperation, encouragement and also understandings.
Thank You So Much and Love You All Forever

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In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I can manage to complete this final year project successfully.

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LIST OF ABBREVIATIONS

2C	-	2-Component
ASTM	-	American Society for Testing and Materials
CF	-	Carbon Fiber
CFRP	-	Carbon Fiber Reinforced Polymer
EoL	-	End-of-Life
FVF	-	Fiber Volume Fraction
FRP	-	Fiber Reinforced Plastic
ISO	-	International Organization for Standardization
PPS	-	Polyphenylene Sulfide Chemical Compound
RTM	-	Resin Transfer Molding
rCF	-	Reclaimed Carbon Fiber
rCFRP	-	Reclaimed Carbon Fiber Reinforced Polymer
SEM	-	Scanning Electron Microscopy
TFP	-	Technical Fiber Product
vCF	-	Virgin Carbon Fiber
vCFRP	-	Virgin Carbon Fiber Reinforced Polymer

LIST OF SYMBOLS

%	-	Percentage
Mpa	-	Mega Pascal
Gpa	-	Giga Pascal
°F	-	Degree Farenheit
E	-	Young's Modulus
σ	-	Stress
ε	-	Strain
mm	-	Millimetre
°C	-	Degree Celsius
g	-	Gram
F	-	Force
A	-	Area
L	-	Length
L_o	-	Original Length

CHAPTER 1

INTRODUCTION

This chapter presents the introduction of the final year project. This project was focused on the mechanical properties of reclaimed carbon fiber composite for secondary application. Besides, this chapter was explained the problem statement followed by the objectives, scopes and outline of the project.

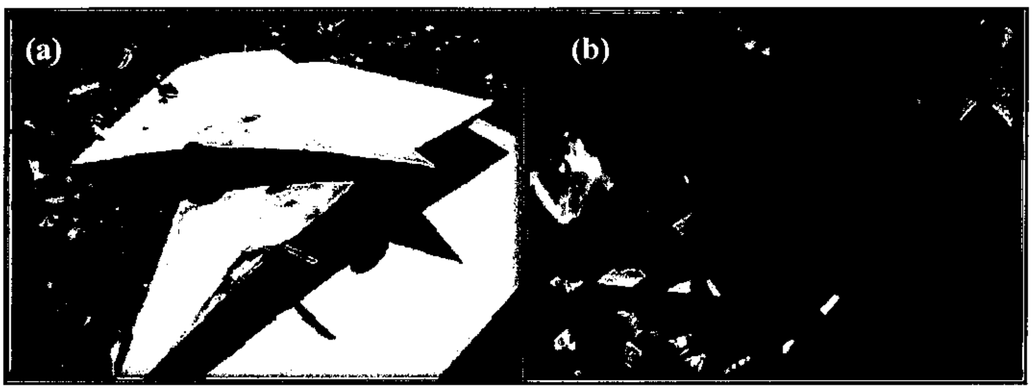
1.1 Background of Study

A composite material is a material produced using at least two constituent materials with fundamentally different physical and mechanical properties that create a material with different attributes from the individual segments.

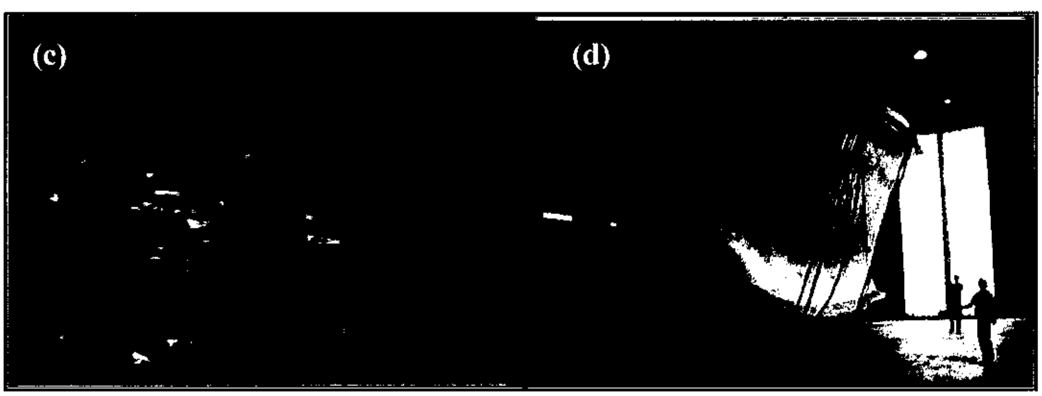
Carbon fiber composite is mostly made using the thermosetting resin, which needs time for molding it. There are several types of composite processes such as hand lay-up, vacuum bagging, vacuum infusion, compression molding, spray up, resin transfer molding (RTM), pultrusion and filament winding. There are two examples of resin such as epoxy resin and polyester resin. The exponential growth within the use of carbon fiber composite discovered throughout the last decades has raised an environmental, economic and legal awareness of their waste produced.

Over the last 20 years, many researchers are trying intensively for disposal routes different to land filling, which is by developing recycling processes to recover the carbon fibers (CFs) from composite waste (Pimenta, 2013). Furthermore, manufacturing processes are adapted to impregnate reclaimed carbon fibers and produce reclaimed composites.

Carbon fiber composites give many benefits to the world. In 2008, the worldwide demands of carbon fiber are close to 35,000 tonnes. This variety is anticipated to double by 2014, representing a rate of growth of over 12% annually (Simon *et al.*, 1967) as shown in Figure 1.1. Currently, carbon fiber reinforced polymer (CFRP) is utilized in a widening scope of uses, mostly in the aircraft industry that has an impressive example such as Airliner A350 and Boeing 787 (Pimenta, 2013).



(a) EoL-aircraft wings (b) Manufacturing cut-offs



(c) Expired of pre-preg rolls (d) Yatch mold

Figure 1.1: CFRP waste (Simon *et al.*, 1967)

Despite all benefits related to CFRPs, the expanding use will increase the quantity of CFRP use. Common sources of waste include the expiration of pre-pregs, producing cut offs, production tools, testing materials and end-of-life parts (Pimenta and Pinho, 2011).

Moreover, the high price and energy intensity of virgin carbon fiber fabricate gives a chance to recover considerable value from CFRP wastes. From an economic viewpoint, the reclaimed carbon fiber product will reduce the cost, used either on their own or in conjunction with virgin carbon fibers. While, from the environmental viewpoint, reusing materials and reducing waste has a high embedded energy which it might be reclaimed in an energy-efficient manner.

This project is about the development of reclaimed carbon fiber composite from composite waste. Reclaimed carbon fiber have been engineered into different types of reinforcement especially in nonwoven mat. This has been developed in commercial scale which lack of optimization of feasibility between the properties in terms of parameter of process involved. In this project, the nonwoven mat fabricated for lab scale and their basic descriptions process compared to commercial reinforcement will respect to performance and durability.

1.2 Problem Statement

Firstly, the problem statement for this project is the type of reinforcement for lab scale. The industry scale were fabricated the many types of reinforcement of carbon fiber especially nonwoven mats. The processes are required the large amount of waste for industry and the process parameter are different. However, for small product in lab scale, it required the different data processing and it is very limited. One of the data processing is the fiber volume fraction and other parameters of process that involved.

Secondly, the distribution of rCF affects the quality of the mat. It is very important because the distribution of rCF will determine the quality of the nonwoven mat. Some industries are used staple for joining the fiber into mat, which is to determine the drapability. However, for a lab scale, staple is not convenience since the size and amount of fiber loading are not suitable with the staple. In addition, it will be affected the drapability. Chemical bonding is one way to produce the mat. However, the effect of the drapability and the mechanical properties are lack of information.

Thirdly, the problem statement is the performance of the reclaimed carbon fiber reinforced polymer (rCFRP) versus the failure mode. rCFRP is depends on the fabrication of composite. Most of the rCFRP used with thermoplastic as this approach use more on filler or short fiber rCF. However, the performances on the nonwoven mat rCF using thermoset are limited since it involves the suitable viscosity of the thermoset despite of the good mechanical properties. The good composite can be achieved by ensuring the matrix are well impregnated the fiber which information on the fractography is important.

1.3 Objectives

(a) To fabricate the nonwoven mat reclaimed carbon fiber in lab scale via wet-laid process.

(b) To investigate the physico-mechanical properties of the reclaimed carbon fiber reinforced polymer (rCFRP) composite.

(c) To correlate the physico-mechanical properties with failure mode via scanning electron microscopy (SEM).

1.4 Scopes

The scope of the research, including:

(a) This project fabricates reinforcement of reclaimed nonwoven carbon fiber in lab scale via wet-laid process.

(b) The physical measurement and observation such as drapability, dispersion and fiber orientation will be conducted on the nonwoven rCF.

(c) The reclaimed nonwoven carbon fiber composite was fabricated via vacuum bagging that attached with resin transfer molding.

(d) Flexural and impact testing used in this project to measure the flexural strength, flexural modulus and impact energy of the composite.

(e) Scanning electron microscopy (SEM) was used to correlate the physico-mechanical properties with a failure mode of the reclaimed nonwoven carbon fiber composite.

1.4 Project Outline

This chapter is shown in good order to deliver a much better understanding regarding generally of the project. An overview of the chapter has been formed to briefly justify the content of the whole chapter. There are 5 chapters which will represent this project. In the following are briefly mentioned about each part of this report.

Chapter 1 is related to the introduction of the project, including background, problem statements, objectives, and scopes. That will be described specifically regarding the reclaimed nonwoven carbon fiber composite.

Chapter 2 summarize on a study relating to the past findings that are done by other researchers and hypothesis involving fiber volume fraction. There are used several sources in order to search out information regarding CFRPs and related subject. The sources used to search in order to support the detail in this part are journal, books, online etc.

Chapter 3 is regarding the project flow which will describe the project plan. It will give elaborated information regarding the method of data is collected and recorded. It also includes techniques utilized inflow chart form.

Chapter 4 is a result and discussion that explains and discusses the report outcome and results of data that has been got from the experiment.

Chapter 5 is a final chapter that will include the conclusion and recommendation. It will relate to the explanation of important results throughout this study. The recommendation for further study based on this project it is also has recommended.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews the study relating to the past findings that are executed by other researchers and theory involving fiber volume fraction. There are used several sources to search out information regarding rCFRPs and related subject. The sources used in order to support the detail in this chapter are journal, books, online etc.

2.1 Introduction

The general definition of a composite material is an aggregation of two or more substances combined to get a set of properties superior than those of its components. Composite materials are used to replace standard engineering metals and alloys for several applications and are usually designed with a particular use in mind, like added efficiency, strength or durability. Their superior thermal characteristics, stiffness and specific strength have made them very competitive within the aerospace industry.

During the previous few years, there was a good deal with interest in recycling carbon fiber reinforced polymer composite (CFRP). There are a number of products in various industries, as well as automotive, workplace and home furnishings, construction and others that using composite materials. The global composites demand in three key markets industrial fields as well as automotive, consumer goods and aerospace for the year between 2013 and 2020 (projected) are shown in Figure 2.1 (Nottingham and User, 2017). The advantages of using the reclaimed carbon fiber composite are lightweight and low manufacturing cost. Several studies have been carried out on the impact of rCF properties as a function of the recycling process on the physical and mechanical performance of composites (Pimenta and Pinho, 2011). Generally, the carbon fibers are mixed throughout