UNIVERSITI TEKNIKAL MALAYSIA MELAKA

RECLAMATION OF AEROSPACE-GRADE CARBON FIBRE PREPREG WASTE THROUGH SECOND IMPREGNATION OF THERMOSET POLYMER VIA HAND LAY-UP PROCESS

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

by

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TAJUK: **RECLAMATION OF AEROSPACE-GRADE CARBON FIBRE PREPREG WASTE THROUGH SECOND IMPREGNATION OF THERMOSET POLYMER VIA HAND LAY-UP PROCESS**

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DECLARATION

I hereby, declared this report entitled "Reclamation of Aerospace-Grade Carbon Fibre Prepreg Waste through Second Impregnation of Thermoset Polymer via Hand Lay-Up Process" is the results of my own research except as cited in references.

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Date	:	29 th June 2012

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree in Bachelor of Manufacturing Engineering (Engineering Materials) (Hons). The member of the supervisory committee is as follow:

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ABSTRAK

Polimer diperpukuh gentian karbon (CFRP) telah digunakan secara meluas disebabkan prestasi cemerlang dan strukturnya yang ringan. Penggunaan komposit ini secara meluas dan berterusan dalam industri aeroangkasa menyebabkan sisanya kian bertambah hasil daripada lebihan skrap pengilangan dan *prepregs* lupus hayat. Faktor alam sekitar dan ekonomi telah mendorong kepada pembangunan penebusgunaan kesan daripada pertambahan penggunaan CFRP ini. Objektif utama penyelidikan ialah untuk membandingkan ciri-ciri penebusgunaan *prepreg* gentian karbon/epoksi dengan *second impregnation* (i-CFPE) dan *prepreg* gentian karbon/epoksi tanpa *second impregnation* (w-CFP). Pengaruh bilangan lapis gentian karbon/ prepreg epoksi dalam sistem laminat komposit juga dikaji. Pengujianan lanjutan untuk mengenalpasti sifat-sifat komposit tersebut telah dilakukan melalui ujian tegangan, ujian hentaman dan ujian lenturan berdasarkan piawaian ASTM. Bagi pengujian terhadap kesan alam sekitar, ujian penyerapan air telah dijalankan. Manakala untuk mengkaji morfologi patahan sampel, pemerhatian melalui mikroskop imbasan elektron (SEM) telah dilaksanakan. Keputusan menunjukkan i-CFPE mempunyai sifat-sifat mekanikal lebih tinggi berbanding w-CFP. Penambahan lapisan laminat komposit nyata meningkatkan penyerapan air tetapi ia menunjukkan penurunan dengan masa pada satu nilai tertentu ditakat ketepuan di mana tiada lagi air diserap dan kandungan air pada komposit kekal malar. Pemerhatian morfologi pada permukaan patah i-CFPE and w-CFP telah mendedahkan bahawa permukaan patah menunjukkan mekanisme penyerapan tenaga seperti gentian patah dan tarik-keluar gentian. Keseluruhannya, kajian awal telah berjaya dan mencapai semua objektif kajian tersenarai. Potensi penebusgunaan prepreg dalam produk umum telah dirumuskan.

ABSTRACT

Carbon fibre reinforced polymer (CFRP) composites have been extensively used because of their excellent performance and lightweight. With continuous and widespread use of these composites in aircraft industries cause its waste constantly accumulated and generated both from manufacturing scrap and end-of-life prepregs. Both environmental and economic factors have driven the development of reclamation routes for the increasing amount of CFRP waste generated. The main objective of this research is to compare the properties of second impregnate carbon fibre prepreg/epoxy laminate composite (i-CFPE) and without second impregnate laminate composite (w-CFP). The influence of the number of layers was also investigated. The laminated composite samples were tested for tensile test, impact test and flexural test in accordance with ASTM standard. For the environmental properties, water absorption test were conducted. Whereas, for fracture morphology of the samples were observed under scanning electron microscope (SEM). The overall results showed i-CFPE has presented higher mechanical properties compared with w-CFP. The increasing number of layers significantly increases the water absorption of the produced laminated composite but decreasing with time as it reaching a certain value of saturation point where no more water was absorbed and the composites water content remained constant. Morphology observation on the tensile fractured surfaces of i-CFPE and w-CFP laminated composites revealed energy absorption mechanism such as fibre breakage and fibre pull-out. In overall, the preliminary research have been successful conducted and achieved all the listed research objectives. Potential of i-CFPE laminate composite in general purpose product are summarized.

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Thank you very much.

DEDICATION

I dedicate this work to my beloved parents for all their love & attention which has made it possible for me to make it up to this point and as well as to my helpful supervisor, *Dr. Noraiham binti Mohamad*, who bestowed me with the courage, the commitment and the awareness to follow the best possible route, by her unmatchable style and by best possible guideline. I would also like to thank all of my colleagues for their assistance, patients and friendship over the past four years.

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LIST OF ABBREVIATIONS

AFRA	Aircraft Fleet Recycling Association
ASTM	American Standard Testing of Materials
CCC	Carbon-Carbon Composites
CF	Carbon Fibre
CFRP	Carbon Fibre Reinforced Polymers
CMC	Ceramic Matrix Composite
CTE	Coefficient of Thermal Expansion
CTRM	Composite Technology Research Malaysia
DGEBA	Diglycidyl Ether of Bisphenol A
DMTA	Dynamic Mechanical Thermal Analysis
E-glass	Electrical Glass
e.g.	Example
EOL	End of Life
et al.	and others
etc.	Et cetera
EU	European Union
ICTA	International Confederation of Thermal Analysis
i.e.	In example
MEKP	Methyl Ethyl Ketone Peroxide
MMC	Metal Matrix Composite
PAN	Polyacrylonitrile
PMC	Polymer Matrix Composite
R-CF	Reclamation of Carbon Fibre
S-glass	Structural Glass
SEM	Scanning Electron Microscopy
Tg	Glass Transition Temperature
TGA	Thermo Gravimetric Analyser
TGGDM	Tetraglycidyl- 4, 4"-DiaminoDiphenylmethane

TGMDA	Tetraglycidyl Methylene Dianiline
UD	Unidirectional
US	United States
UTM	Universal Testing Machine
Wt%	Weight Percent

CHAPTER 1
INTRODUCTION

1.1 Introduction

Nowadays, carbon fibre reinforced polymers (CFRP) are becoming mainstream engineering materials. These high performance composite materials have superior properties that give them an edge over traditional materials which include longer life cycles due to high fatigue strength, increased corrosion resistance, improved fire resistance, easier design because of functional integration, possibility of complex shapes and lightweight. Due to CFRP benefits in terms of weight saving and performance have caused to increase usage of these materials especially for aerospace, automotive and industrial structures. Besides, with these increasing usage of composites in space and military systems, as well as in commercial aircraft development, is expected to be continuing far into the foreseeable future (Allred, 1999).

According to Pimenta (2010), he estimate the world-wide demand for carbon fibres reached approximately 35 000 tone in 2008 and this number is expected to double by 2014, representing a growth rate of over 12% per year. With this surge in material use, waste is constantly accumulated and generated both from manufacturing scrap and end-of-life prepregs. End of life(EOL) prepregs can be defined as expiry life span of the prepregs or are obsolete in their respective industry. This composite waste is usually no longer used or needed. Although there are multiple industries in which the EOL waste composite exists, the aerospace industry is normally face major problems of when dealing with these EOL waste material. This is due to its difficulties to be recycled. Along with the increase in aerospace-grade carbon fibre

prepreg waste (CFP) there must be an equally important and growing concern of these CFP management. In the last four decade, CFP composite materials have become an integral part of society. In the past shows that CFP were regarded as non-recyclable. Presently, most of the CFP waste is landfilled (Pickering, 2006). Increase of environmental awareness and new environmental protection laws made it unacceptable to dispose all composites on landfill sites (Buggy and Farragher, 1995). The land filling of CFP has many environmental and cost related concerns. A need for reclamation of carbon fibre prepregs has arisen and technologies have been developed to recover the carbon fibre from the composite waste. By developing this method, it will significantly reduce for carbon fibre disposal at save, low cost and thereby producing a positive impact both environmentally and economically.

There is considerable interest and noble aims in this research where to produce an alternative way other than landfilled and burned the CFP, it also can be introduced by reclaimed through second impregnation. Thus, overall of this research was to investigate the properties of laminate composite based aerospace-grade carbon fibre prepreg waste where the laminated composites were prepared via hand lay-up process and compression moulding. Furthermore, this study was carried out with and without second impregnation. In this research work, the influence number of plies to the mechanical properties of carbon fibre prepreg/epoxy laminate composites was investigated using related testing and analysis. The data analysis then revealed the potential of the second impregnate carbon fibre prepreg/epoxy laminate composite (i-CFPE) whether in engineering or for general purpose product.

1.2 Problem Statement

The growth in use of CFRP composites from 15% in 1990 (A320) to over 50% in 2010 (A380) for airframe structures and high lift components was demonstrated (Baker et al., 2004). There are problems connected with the increasing scrap and end of life of CFRP because the are very hazardous waste to human and environmental health. Recently, it creates an environmental awareness and cost related concerns, that being the reason many aerospace-grade carbon fibre prepreg waste (CFP) need

to be reclaimed these days. Allocated to this problem, a new approach to composites reclamation is needed to the researchers and manufacturers other than burning method of the CFP due to environmental pressure derived from the raising used of CFP besides it difficulties and hazardous in degradation in a landfill.

In fact, disposing of hazardous materials is both time consuming and a cost burden from both the manufacturing and end of life (EOL) disposal perspectives. The cost to dispose of a hazardous waste can be more than 20 times the disposal cost of a non-hazardous solid waste. These extra costs incur because when a waste is classified as hazardous, appropriate actions must be taken to ensure that it does not pose a threat to human health and the environment if land-disposed (Boeing, 2003). Therefore, instead of CFP is landfilled, by finding a proper solution for examples reclamation of CFP through second impregnation will helps to reduce cost burden of manufacturers besides we can improve waste management of the CFP. On the other hand, reclamation of aerospace-grade carbon fibres waste has environmental and business benefits. According to Wood (2010), he explained that carbon fiber reclamation was an attractive market niche because it's driven not just by the financials, but also by government research incentives, and by the desire for manufacturers to have green manufacturing processes and products.

Reclamation of carbon fibre prepreg waste is one of the alternative method used to reduce the amount of these hazardous CFP but there were still lack of research be conducted in this field. Besides, difficulties in reclaiming method for example due to (i) their complex composition (fibres, matrix and fillers), (ii) the cross-linked nature of thermoset resins (which cannot be remoulded), and (iii) the combination with other materials (metal fixings, honeycombs, hybrid composites, etc.). Besides, it is considerably not been economic to reclaim CFP and where their future use be more limited (Turner, 2009).

In addition, there is the fluidised bed reclamation method in which pre-fragmented waste material was 'fluidised' by having a high-temperature around 550°C fluid or gas passed through it from beneath in the presence of air, the ensuing pyrolysis and oxidation resulting in progressive separation of its components. These methods can