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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF MECHANICAL BEHAVIOUR OF RECLAIMED CARBON FIBRE REINFORCED POLYPROPYLENE BY USING COMPRESSION MOULDING VIA RESPONSE SURFACE METHODOLOGY.

Submitted in accordance with the requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Faculty of Manufacturing Engineering) (Hons)

by

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Tajuk: **OPTIMIZATION OF MECHANICAL BEHAVIOUR OF RECLAIMED CARBON FIBRE REINFORCE POLYPROPYLENE USING COMPRESSION MOULDING VIA RESPONSE SUREFACE METHODOLOGY**

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Date : 6 JUNE 2018

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee are as follow.

....

(Dr. Zaleha Binti Mustafa)

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ABSTRAK

Pada masa kini, terdapat banyak penggunaan harian menggunakan pembuatan serat karbon. Serat karbon mempunyai banyak kelebihan seperti ringan tetapi kekuatan tinggi. Inilah mengapa serat karbon menjadi lebih dan lebih popular dalam industri aeroangkasa dan automotif. Walau bagaimanapun, pembaziran komponen yang berasaskan serat karbon meningkat menjelang tahun apabila permintaan serat karbon meningkat. Kaedah pengendalian semasa serat karbon sisa adalah melalui tapak pelupusan dan pembakaran tetapi ia akan mendatangkan kesan negatif kepada alam sekitar. Kitar semula serat karbon sisa melalui pirolisis boleh menyelesaikan masalah tapak pelupusan atau pembakaran dan mengekalkan sumber. Suhu pirolisis telah dioptimumkan oleh kajian terdahulu. Selepas itu, serat karbon yang diterbalikkan kemudiannya dimampatkan dengan termoplastik yang lain seperti polipropilena untuk membentuk komposit baru dengan menggunakan pengacuan mampatan. Walau bagaimanapun, masalah membasahkan antara serat karbon dan polipropilena mempengaruhi kekuatan komposit. Sifat mekanikal komposit adalah dioptimumkan dengan memantau parameter pemprosesan mampatan dengan menggunakan Design of Experiment (DOE). Parameter yang terlibat adalah suhu mampatan, masa pegangan untuk menguatkan dan juga peratusan pemuatan serat komposit. Akhirnya, komposit itu diuji dengan ujian tegangan untuk menilaikan kekuatan tegangan komposit..

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ABSTRACT

Nowadays, there are a lot of daily usage are manufacture using the carbon fibre. Carbon fibre have a lot of advantages such as light weight but high strength. These are why carbon fibre become more and more popular in the aerospace industry and automotive. However, the waste of the components that are based on carbon fibre increases by year as the carbon fibre demand increases. The current handling method of the waste carbon fibre are through landfill and incineration but it will bring negative impact to the environment. Recycling of the waste carbon fibre through pyrolysis can solve the problem of landfill or incineration and sustain the resources. The pyrolysis temperature has been optimized by previous study. After that, the reclaimed carbon fibre is then compressed with the other thermoplastic such as polypropylene to form a new composite by using the compression moulding. However, the wetting issue between the carbon fibre and the polypropylene influences the strength of the composites. The mechanical behaviour of the composite is then optimized by closely monitoring the compression processing parameter by using Design of Experiment (DOE). The parameter involved are the compression temperature, the holding time for it to solidify and also the percentage of the fibre loading of the composites. Finally, the composite are tested with tensile test to evaluate the tensile strength of the composites.

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DEDICATION

Only

My beloved father, Lee Jek Meng

My beloved mother, Poon Yoke Har

My beloved brothers Lee Woei Jian andLee Weoi Derk

My lovely girlfriend Ong Ching Wei

For giving me moral support, money, cooperation, encouragement and also understanding

Thank You So Much & Love You All Forever

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variances
ASTM	-	American Society for Testing Materials
BBD	-	Box-Behnken Design
CFRP	-	Carbon Fibre Reinforced Polymer
DOE	-	Design of Experiment
GF	-	Glass Fibre
HM		High Modulus
HT		High Tensile Strength
PA	-	Polyamide
PAN	-	Polyacrylonitrile
PMI		Polymethacrylimide
PP	-	Polypropylene
RSM	-	Response Surface Methodology
UHM		Ultrahigh Modulus
UT-CTT	-	Ultra-Thin Chopped Carbon Fibre

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LIST OF SYMBOLS

mm	-	Millimetre
vol. %	-	Volume Percentage
wt. %	-	Weight Percentage
^0C	-	Degree Celsius
GPa	-	Giga Pascal
Min	-	Minute
MPa	-	Mega Pascal
N/mm	-	Newton per Millimetre

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Carbon fibre are fibre that composed mostly of the carbon atoms and it about 5 to 10 micrometres in diameter. The advantage of carbon fibre are high stiffness, low in weight, high temperature tolerance, high chemical resistances and also low thermal expansion compare to the other fibre. With this kind of properties, carbon fibre are highly recommended in aerospace, military, and also automotive. However, when composed with other fibre such as plastic fibre and glass fibre, it becomes relatively expensive.

Nowadays, carbon fibre are usually used as reinforcement with the other kind of material to form another composite. When carbon fibre are reinforced into a plastic resin or wound to forms carbon-fibre-reinforced polymer CFRP, the composite has a very high strength-to-weight ratio and it is very rigid although somewhat brittle. Besides that, carbon fibre are also reinforced with other type of materials such as graphite, to form carbon-carbon composites. This kind of carbon fibre have a very high heat tolerance.

Carbon fibre reinforces polymer CFRP composites are used to manufacture numerous product. This is due to the good properties of the CFRP which are light weight and it also a strong material. CFRP composites is a term used to describe a fibre reinforces composite material that uses carbon fibre as the primary structural component. It should be noted that the "P" in CFRP can also stand for "plastic" instead of "polymer". Generally epoxy, polyester and vinyl ester are the most common thermosetting resin that usually use for CFRP composite.

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Nowadays, the aircraft and automotive manufacture want to reduce the weight of the component, reduce the carbon emission and increase the energy efficiency. It help to promote the growth of carbon fibre demand (Malveda, 2016) The global market for carbon fibre is growing by more than 8% per year through 2020 (Holmes, 2017). This growth is because of the application of industry such as the automobiles, sporting goods and the manufacturing of aircraft. It currently consume about 60% of global carbon fibre demand in industrial application and the automotive.

It can be said that aerospace and space are the first industries to adopt carbon fibre. The primary reason that carbon fibre adopted by the aerospace industry is due to their light weight properties. In addition, the high modulus of the carbon fibre allow it to replace most of the alloy such as aluminum and titanium. With the slightly different in the weight can cause a serious differences in the fuel consumption. This is why Boeing's new 787 Dreamliner has been the bestselling passenger plane in history due to most of the plane's structure are made from carbon fibre reinforced polymer (CFRP) composite.

1.2 Problem Statement

Carbon fibre reinforced polymer (CFPR) has been widely used in many sector such as aerospace and automotive industries. The increasing use of the carbon fibre reinforced polymer (CFRP) directly increase the amount of the waste of component base on carbon fibre. Approximately 8500 commercial planes are expected to reach end-of-life dismantlement by 2025.The raw material for synthesis carbon fibre are petroleum while petroleum are non-renewable resources. The current handling method of the waste of CFRP are disposal in landfills however it already run out of space and may cause pollution and negative impact to the environment.

Compression moulding is one of the most common used composite processing method in polymer matrix composite. In compression moulding, the mechanical properties greatly depend on their variable such as temperature, pressure and holding time. Temperature is one of the main crucial parameter, where if the material is compressed too long at high temperature, it might degrade and good wetting might be sacrificed.

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Thus, optimization of compression moulding parameter need to be carried out to evaluate against the composite properties.

1.3 Objectives

This objectives are as follows:

1. To optimize the process temperature of the compression moulding of reclaimed CF-PP composite.

2. To optimize the soaking time of the compression moulding of reclaimed CF-PP composite.

3. To optimize the fibre loading of reclaimed CF-PP composite.

1.4 Scopes of the Research

This research is focus to understand the compression parameter such as temperature and the soaking time that may influences the final properties of the composite. Firstly, the uncured unidirectional prepregs with 70% of carbon fibre and 30% of epoxy is treated with pyrolysis process to remove the epoxy. Then, the reclaimed carbon fibre is reinforced in PP at 30 wt. %. The temperature for the compression moulding is set at three different temperature which are 170° C, 180°C and 190°C and different soaking time which are 3 min, 6 min and 9 min. The composite is compressed at selected temperature. The mechanical test use in this study is tensile test.

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CHAPTER 2

LITERATURE REVIEW

This chapter basically reviews regarding the background and previous studies on carbon fibre, epoxy and compression moulding process.

2.1 Carbon Fibre

Carbon fibre are fibrous carbon materials with carbon content more than 90% and carbon is a raw material for carbon fibre. It exists in many different allotropic forms which are graphite, diamond and fullerenes. Basically, the carbon atoms are arranged in a hexagonal shape. The carbon atoms are strongly bonded in the layer and held by a weak van der Waals forces. Graphite is a highly anisotropic material due to this structure.

Carbon is the one of the light elements with a density of 2.27g/cm^3 while carbon fibre have a density values ranging from 1.6g/cm^3 to 2.20cm^3. The density of the carbon fibre are depending on the processing condition. (Balasubramaniam, 2014)

2.1.1 Type of Carbon Fibre

In the market, there are variety of carbon fibre that comes with different properties show in Table 2.1. The main cause of these properties is due to the raw material that used during the manufacturing stage. The stiffness of the carbon fibre are controlled by the thermal treatment during the manufacturing process. The carbon orientation of the strongest carbon links along the fibre direction and the fibre content can influences the stiffness of the

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carbon. The PAN base carbon fibre have 3 types and categories which were classify as high tensile strength (HT), high modulus (HM), and ultrahigh modulus (UHM).

Table 2.1: Properties of commercial carbon fibre. (Mallick, 2007)

Type of Carbon fibre	Typical Diameter (μm)	Density (g/cm^3)	Tensile Strength (GPa)	Tensile Modulus (GPa)	Strain-to-Failure (%)
PAN based					
1) T-300	7	1.76	3.65	231	1.40
2) AS-1	8	1.80	3.10	228	1.32
3) AS-4	7	1.80	4.07	248	1.65
4) T-40	5.1	1.81	5.65	290	1.80
5) IM-7	5	1.78	5.31	301	1.81
6) HMS-4	8	1.8	2.48	345	0.70
7)GY-70	8.4	1.96	1.52	483	0.38
PITCH based					
1) P-55	10	2.10	1.90	380	0.50
2) P-100	10	2.15	2.41	758	0.32

2.1.2 Properties of Carbon Fibre

The properties of the carbon fibre depend on the raw material and the process that used to manufacture the carbon fibre. The two main raw material that used in manufacture the carbon fibre are pitch and polyacrylonitrile (PAN). The pitch fibre are less costly and it have a lower strength compare to the PAN fibre. However, PAN fibre dominate the high performance market for the aerospace application. This is because the PAN fibre can be manufactured with a variety of stiffness and strength values. (Barbero, 2010)

Carbon fibre are available with a width range of stiffness value that can controlled by the thermal treatment for both of the PAN and pitch-based carbon fibre. The maximum operating temperature for the carbon fibre varies from 315°C to 537°C. Carbon fibre are stiffer compare to glass fibre. Carbon fibre have a better fatigue properties to the composite by minimizing the amount of strain bear by matrix when the load being applied. Besides that, the stress corrosion phenomenon (static fatigue) also less marked for carbon fibre. (Barbero, 2010)

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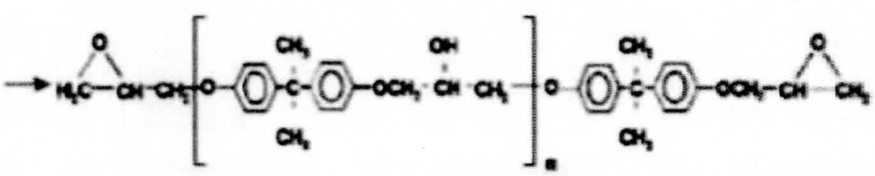
Carbon fibre have a low shock resistance due to their high rigidity and high fragility. The good electrical resistance of the carbon fibre will make galvanic corrosion take place once the carbon fibre are in electrical contact with the metal. As a result, an insulting barrier needed to be create between the carbon fibre composite and the metal.

2.2 Epoxy Resin

Epoxy resin is one of the type of polymeric material that normally used as a matric in a composite. Besides that, epoxy resin are also a low or high molecular weight polymer. It normally consists at least two group of epoxide. It is called epoxy due to it contain epoxide functional group. The group of the epoxy resin are usually refer as an oxirane group or glycidly group. Generally, there are different type of epoxy resin that available in the market. The different of the epoxy resin can be differ by their properties and also the additives added. Epoxies are well known for their good adhesion, chemical and heat resistance and also the electrical resistance. Besides that, epoxy is also widely used in application as matrix in composite due to its excellent adhesion and capable to retain the strength at elevated temperature.



Base Epoxy Resin (n = 1 to 15)

Figure 2.1: Chemical structure of Epoxy resin.

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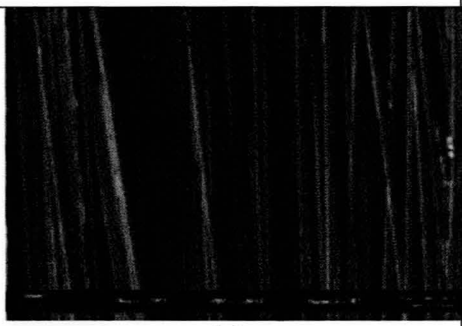
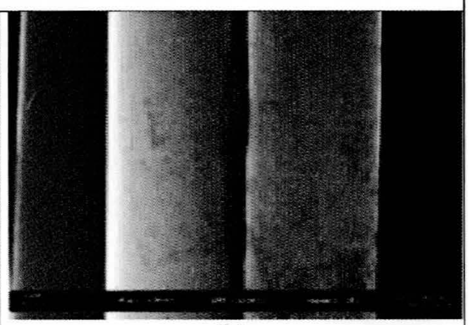
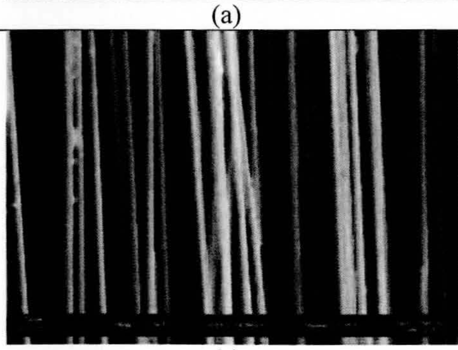
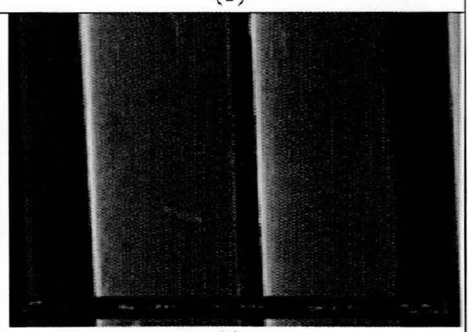
2.3 Pyrolysis process for reclaiming Carbon Fibre

Sharifuddin (2017) investigated the effect of temperature in pyrolysis process for reclaiming carbon fibre at three different temperature which were 450^0C, 500^0C and 550^0C. The SEM image for the reclaimed carbon fibre were as shown in Figure 2.2. Form the Figure 2.2a, at the low magnification, the epoxy matrix can be observed clearly embedded to the carbon fibre. Besides that, at the high magnification (Figure 2.2b), the surface of the carbon fibre were rough due to the existed epoxy residue that didn't burn off. When the temperature of the pyrolysis process increased to 500^0C, the surface of the carbon fibre become smoother since there were only remain some amount of the epoxy matrix on the carbon fibre as shown in Figure 2.2c and 2.2d. As the temperature increased by 50^0C, the surface of the carbon fibre become smoother than ever and this indicate that the most of the epoxy matrix were burn off as shown in Figure 2.2e and 2.2f. However, the carbon fibre tend to degrade once it treated with a higher temperature. (Sharifuddin, 2017)

Thermal parameter	Low magnification	High magnification
450°C	 (a)	 (b)
500°C	 (c)	 (d)

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