UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TRIBOLOGICAL STUDY USING PIN-ON-DISC FOR POLYROPYLENE AT DIFFERENT CARBON FIBERS FILLER LOADING

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering Technology (Process & Technology) with Honours.

by

NURUL ZARIFAH BINTI KAMAR
B071410747
931119045472

FACULTY OF ENGINEERING TECHNOLOGY
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DECLARATION

I hereby, declared this report entitled “Tribological Study Using Pin-On-Disc for Polypropylene at Different Carbon Fibers Filler Loading” is the results of my own research except as cited in references.

Signature	:	…….
Author‟s Name	:	NURUL ZARIFAH BINTI KAMAR
Date	:	……

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Process & Technology) with Honours. The member of the supervisory is as follow:

……

(Mr Hairul Effendy Bin AB Maulod)

ABSTRAK

Pada masa kini, permintaan antarabangsa yang kukuh untuk komposit memacu pengembangan industri berskala industri dan automotif. Disebabkan sifat-sifat tidak stabil serat karbon, pengubahsuaian sifat mereka adalah perlu untuk memperbaiki. Fleksibiliti polipropilena dalam produk tujuan umum ditangani untuk menyokong alam sekitar hijau dengan bahan kitar semula. Mengitar semula serat karbon digunakan sebagai pengisi untuk Polipropilena dan sebagai bahan matriks utama dengan rumusan yang berbeza untuk meningkatkan sifat fizikal dan mekanikal mereka. Perumusan pengkomposan yang optimum dari sebatian bahan diperhatikan pada gabungan polipropilena dan serat karbon berdasarkan 100 wt. % daripada polipropilena (PP) dan pemuatan pengisi serat karbon yang berbeza pada 3wt%, 10wt% dan 20wt%. Untuk meningkatkan interaksi antara polipropilena dan serat karbon, anhidrida maleik digunakan pada komposisi 3wt% dan 5wt%. Polipropilena dan serat karbon bersatu bersama dengan menggunakan Pengadun Dalaman dan komposisi dibuat ke dalam lembaran nipis menggunakan Mesin Mampatan Mampatan Panas. Komponen yang menjalani beberapa ujian termasuk Pin pada Cakera, Jenis Kekerasan Shore D dan Mikroskop Optik untuk mencirikan sifat-sifat komposit PP / rCF. Berdasarkan kajian, semakin tinggi peratusan berat rCF akan meningkatkan sifat kekerasannya. Tambahan pula, untuk ujian tribologi, peratusan berat tambahan serat karbon kitar semula akan meningkatkan rintangan haus dan pekali geseran matriks PP.

ABSTRACT

Nowadays, strong international demand for composite is driving expansion of industrial-scale and automotive industry. Due to unstable properties of Carbon Fiber (CF), the modifications of their properties are necessary to improve. The versatility of polypropylene in general purpose products was addressed to support green environmental by recycling materials. Recycle carbon fiber was used as filler for Polypropylene and as a primary matrix material with different formulation in order to improve their physical and mechanical properties. The optimum compounding formulation of the material compound was observed at the combination of polypropylene and carbon fiber based on 100 wt. % of the polypropylene (PP) and different carbon fibers filler loading at 3wt%, 10wt% and 20wt%. In order to improve the interfacial interaction between polypropylene and carbon fiber, maleic anhydride was used at composition of 3wt% and 5wt%. Polypropylene and carbon fiber were blend together by using Internal Mixer and the composition were fabricated into thin sheets using a Hot Compression Molding machine. The compound undergone a few testing includes Pin-On-Disc, Shore Hardness Type D and Optical Microscope to characterize the properties of PP/rCF composites. Based on the study, the higher the weight percentage of rCF will improve the properties of its hardness. Furthermore, for testing tribology, the addition weight percentage of recycle carbon fiber will improved the wear resistance and coefficient of friction of the PP matrix.

DEDICATION

This report is dedicated to Mr. Hairul Effendy Bin Ab. Maulod for without his early inspiration, coaching and enthusiasm, none of this would have happened. This dedication is especially dedicated to my parents. To my father, Kamar Bin Md Sab for his ongoing love and support, he also taught me to trust in Allah and believe in hard work and to my mother who could not see this final report completed. I also dedicate this report to my family who always support me with their unconditional love that motivates me to set a higher target in completing this final year project. This dedication is also dedicated to my beloved friends that have provided me with a strong love shield and always surround me and never lets any sadness enter inside.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

CFRP	-	Carbon Fiber Reinforced Polymers
EOL	-	End-of-Life
CF	-	Carbon Fiber
OM	-	Optical Microscope
MMC	-	Metal Matrix Composites
PMC	-	Polymer Matrix Composites
CMC	-	Ceramic Matrix Composites
OMC	-	Organic Matrix Composites
AFRA	-	Aircraft Fleet Recycling Association
PP	-	Polypropylene
CBp	-	Carbonized Bond Particles
CFPs	-	Carbon Fiber Prepreg waste
MA	-	Maleic Anhydride
PP/rCF	-	Polypropylene/ Recycle carbon fiber
SiC	-	Silicon Carbide
COF	-	Coefficient of Friction
N	-	Normal Force
μ	-	Friction
Fr	-	Friction force
Fn	-	Normal force.
K	-	Specific Wear Rate
L	-	Sliding Distance
Δm	-	Mass loss of the samples

ρ	-	Density
ASTM	-	American Standard Testing Method
PEEK	-	Polyetheretherketone
MAPP	-	Maleic Anhydride Grafted Polypropylene
HNO_3	-	Nitric Acid
rCFs	-	Recycled Carbon Fiber
ΔV	-	Volume difference

CHAPTER 1
INTRODUCTION

This chapter will explain the overview of the study and the main purpose of this study. The chapter includes the background of the study, problem statement, objectives that is expected to be achieved and the scope of the study that is going to be conducted.

1.1 Background of Study

Nowadays, the demand of composite product is increasing. The use of composites in many applications is resulting in growth of volume of composite products. Generally, composite had been used in many applications of industry such as automobile, aerospace and renewable energy industries. Aerospace industry is the biggest consumer of composite product with approximately 80% of the total composite production (Campbell, 2011).

The main issues on composite are the recycling method. There is no solution for the recycling issue due to the existing nature of heterogeneity, in particular for the thermoset-based polymer composites. The actual method and recycling which begin from end-of-life (EOL) of certain product is needed for the future waste management system. The recycling method contributes in improving the energy resource and energy saving for the world. Many technologies are focusing more on reinforcement of fibers be commercialized, it have been developed on mechanical recycling, thermal recycling, and chemical recycling. However, there are some of major commercialization barriers such

as lack of adequate markets, high recycling cost, and lower quality of the recycles (Yang et al, 2012).

The most familiar composites that have been widely used in this high technology are the application of carbon fiber reinforced polymers (CFRP). High performance composite material gives more useful properties as compared to the traditional materials in the way of 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. The applications of carbon fiber reinforced polymer are built bigger and diversifying. Since 2010, the demand for carbon fiber is 39,280 metric tons for high application such as aerospace to sport equipment and it will increase the demand into 89,260 metric tons in 2015 (Wong et al, 2012).

Based on the demand for industry, the high grade carbon fiber is expensive and valuable due to economically and effectively to recycle and recover (Park et al, 2009). Most of carbon fiber before or after processing is producing scraps as known as wasted carbon fiber. The form is usually seen like cuts-off the process of production, out of life prepreg, and end of life cycle of components. Nowadays, the wasted carbon fibers have already hit a significant limits and it will growing high in future, in theoretical, composite material is not applicable to recycle. Recently the increased of cost of landfill for requirements legislative and around 85% demanded of vehicles disposed must recycled after 2015 was reported (Meredith et al, 2012). In fact, carbon fiber reinforced polymers (CFRP) have come into practical use for the aerospace and automotive industries instead of iron and aluminum alloys. Due to their properties and behavior of composite been contributed to higher fuel efficiency and lower levels of emissions. Therefore, the demand for CFRP‟s has dramatically increased in recent years (Okayasu et al, 2013).

The cost for manufacturing the carbon fibers are limited and usually it used to the area in high cost application in which to gain a good performance in mechanical and weight saves. Therefore, by recycled the wasted carbon fibers may have potential to get

a cheaper cost than virgin fiber and it will give a new market change and opportunities in industry (Wong et al, 2012). Consequently, the carbon fiber is commercialize in raw and recycled but mostly a new development for recycled is been conducted which to get a good properties as raw material. However, a few studied have been reported on in this report about the composite of recycled carbon fiber with reinforcement of polymer (PMC).

According to Pimenta et al. (2010), he estimate the demand of carbon fiber in world will reached approximately 35 000 tone in 2008 and expecting to be double in 2014, by representing a growth rate of over 12% per year. With this surge in material use, waste is constantly accumulated and generated both from production 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 composite EOL waste 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.

According to Nirmal et al. (2015), the tribology is related to relative motion in which to study the friction, wear and lubricant of the interacting surfaces. Generally, the concept of tribology is important since most of design applications are related to wear and friction. In other words, the meaning of tribology is contacting of solid mechanism and nature of surface interaction. Many researchers have been introduced for advance material as substitute to conventionally used materials as the material has been modified which are excellent in wear and friction, light weight and longer life span.

For this study, the focus on tribology of polymer and based on Rymuza (2007), the tribology of polymer is different between metal and ceramic material in many kind of application. The friction contacts in comparison to metal and ceramic materials are related to chemical and physical structures as well as surface and bulk properties. Therefore, the usage of polymer are easy to modified for both surface and bulk because the polymer have very low surface free energy and also low viscoelastic properties.

Based on Korpela et al. (2012), most of study on tribology mechanism is concerning the wear and friction properties of material. Meanwhile, to reduce the coefficient of friction (COF) and increase wear performance, they carried to study the mechanism of tribology properties. Others, it also focuses in searching alternative choice in order to increase the static or sliding COF and wear friction.

1.2 Problem Statement

The new engineering materials possibilities are the carbon fibers and theirs composites. It helps to enhance the properties of the materials such as mechanical, physical and thermal properties, and make it more familiar due to its high strength & stiffness, and low density. The most challenging of using the new material are the things that need to do with it when the structure made is ready to be decomposed. Generally, the options are to throw it away, decompose or recycle.

Carbon fiber is very expensive to manufacture from the point of raw material which needs high energy cost to convert the polymer base into carbon fiber. The composite have a behavior in long life spend in the landfill or industry. The usage of carbon fiber composite increase, it concerns the end life of product and wasted from manufacturing is potential tonnage usage of carbon fiber. Therefore, in some development there are varieties of recycling needs to attend for these valuable materials. In other aspect such as the disposal costing of waste material are too expensive and unprofitable as compared to their usage. In addition, it will give harmful effects to the environment such as air pollution, water pollution and hazardous condition in landfill. Thus, some alternatives to overcome this issue by recycling or reusing again the carbon fiber reinforced polymer in many ways like oxidation and thermal decomposition like pyrolysis process and fluidize. The challenging situation for recycled composite that composed with multiple phases is the behavior of thermosetting matrix are not suitable be remolded and the resin mostly containing other material which might produce noxious combustion from product.

In previous study, the wasted disposal issued have been solve by recycled the waste of material. Meanwhile, it has some several defect or lack to recycling fiber reinforced polymer due to method and experience. The scrap must be cured and subsequently being use as a filler of the material of polymer. Therefore, the method that might be carried for this study is expensive and insufficient demand for milled CFRP (Park et al, 2009). Besides, the composited wasted are typically being disposed in landfills or incinerated without recycling. The composite wasted is related to inert compared to others wasted because it not produces methane gas or leachate gas. Therefore, the new development should be developing in order to reduce the amount of the wasted disposal and also reduce the impact for environment.

The usage of polymer composite is being widely spread out in industry and science. Most of the studied are more concern to the polymer-metal contact pairs and polymer-polymer contact has been focus to study the experiment and theoretical method. The different carbon fiber filler loading will modified the surface properties because the wear and friction behavior are influenced by profile of the surface, periodic textures and structure of different scales is related to wear and friction behavior of metallic surface and inorganic material. The new compounds of carbon fibers into thermoplastic are expecting to improve the properties of physical, mechanical and tribological of the composite. Very little and limited references had been studied the effect of reinforcement on the mechanical and tribological properties of thermoplastic materials filling by recycled carbon fibers as these method enhance the properties performance of thermoplastic by filler

1.3 Objectives

The objective of the project is to:-

i. To study the current formulation of polypropylene reinforced with carbon fiber.
ii. To prepare the compound of recycled carbon fiber reinforced polypropylene via melt compounding.
iii. To study the tribological properties using pin-on-disc method for polypropylene at different carbon fibers filler loading

1.4 Scope

The study on this topic can be benefit for certain circumstances. This research is "Tribological study is using Pin-On-Disc for Polypropylene at different Carbon Fibres Filler Loading" through the mixing material using internal mixer and tests their properties. The scopes of this study is focusing more on mechanical and tribological properties of polypropylene and recycle carbon fiber through the melt compounding method and its properties effect and analyzed by using the Pin-On-Disc and Shore Hardness Type D Test. The findings will be further supported by the analysis of Optical Microscope.

1.5 Organization of Research Study

This research study is divided into five chapters that discuss the analytical and experimental research performed. This dissertation shows the recycled carbon fiber used as a reinforcement. The effects of different loading of carbon fiber have been studied, in search of improvements on their physical and mechanical properties. The organization of this research study is as follows. This dissertation has been organized into 5 chapters.

The first chapter begins with an introduction about the research study and also brief about objectives, problem statement, significant of study and the thesis overview.

Chapter two begins on the literature background of this study. It discusses on the history of composite, types of composites and matrices. The important element that included in this chapter is about the mechanical properties and used of carbon fiber, polypropylene and the wear behavior of polymer composite.

Chapter three provides details explanations on the methodology used for overall research work, raw materials, procedure property analysis that had been done. In this chapter four, instead of investigation of wear behavior of polypropylene and carbon fiber composite, also want to understand the relationship of wear rate with different loading of carbon fibers. The final chapter (Chapter 5) concludes the overall results obtained from this research. In this chapter, it explains either the objectives of this study are achieved or not. The recommendation for future project also has been included in this Chapter 5.

CHAPTER 2
LITERATURE REVIEW

In this chapter, it will explain about the previous research that has been writing from the numerous of the researcher which come from the internet online, journals, article and books about the topic that is related to this final year project study. This chapter also explains about the overview of the composite from polypropylene and carbon fiber at different filler loading. The success of a design and material testing also depends on the creativity of designers and the use of appropriate technology to meet the needs of effective and functional. The design and study is ongoing process that involved creative problem solving is known as a literature.

In the production this project, all theory and information of material substance used, production and testing in relation this project has been described to achieve objective of the project those implemented.

2.1 Composite

Over thousand years, human already used materials in their own daily life. The history start from the background of human progress indicates that the implementations of materials are helpful in increasing the strengths, science, material science and innovation. It shows that the human has their own control limits in order to understand and change the nature.

In the word "Composite" itself indicate that it is a combination of more than one types of material in order to produce a useful third material. The useful of third material

can be analyzed on a macroscopic scale where it also can be determined using the naked eyes (Campbell, 2010). The design can be attained from the mixture of properties of any single material and include each one of the components characteristics. There are two types of phases in composite which are matrix phase and dispersed phase. As referred to Figure 2.1, it shows that the schematic of composite on each type of phases.

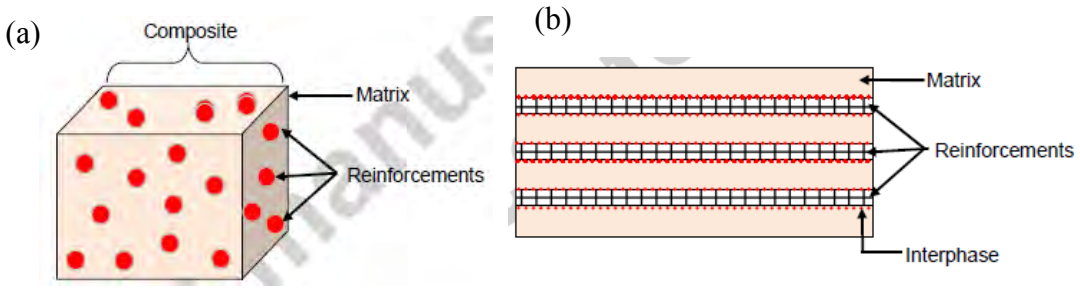

Figure 2. 1: Schematic of a composite material: (a) Matrix, reinforcement and interphase between composite material (Nirmal et al, 2015).

On the other hand, some of the composites are exits in a different combination of metals, ceramics, and polymers, whereas the materials that found naturally also can include as composites such as wood and bone. Somehow, most of the composite are synthetic (Callister & Rethwisch, 2007).

2.2 Matrices

Most of the materials use metals and polymers as matrix materials which will help to increase the fracture toughness (Callister & Rethwisch, 2007). It can be wither ceramic, metal or polymer. In the first place of composite are the fiber-matrix adhesions. The function of fiber that reinforced with composite is to carry a charge to the hard fibers through the shear stresses at the interface. It requires a strong bond between the polymer matrix and fibers. The lack of adhesion will decrease the strength of the