FRICTION AND WEAR PROPERTIES OF POLYMER COMPOSITE MATRIX MADE BY TAPIOCA STARCH

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DECLARATION

"I hereby declared that this report entitle "Friction and Wear Properties of Polymer Composite Matrix Made by Tapioca Starch" is the result of my own work except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree."

Signature	: …………………………...
Name	: Siti Norshamimi bt Dollah
Date	: …………………………..

APPROVAL

“I hereby declared that I have read through this report entitle “Friction and Wear Properties of Polymer Composite Matrix Made by Tapioca Starch” and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Mechanical Engineering with honours”

Signature : ……………………………………..

Supervisor’s Name : Dr Mohd Rody Bin Mohamad Zin

Date : …..

DEDICATION

To my beloved father and mother.

ABSTRACT

The main purpose of the study is to investigate the friction and wear properties of polymer matrix composite made by tapioca starch as well as to prepare and characterized them at different starch percentage. Polypropylene (PP) mixed tapioca starch were prepared using Hot Press Machine in various weight percentage concentrations ranging from 0%, 10%, 20% and 30% of starch filler. The results from the sample preparation shows that the colour of sample formed is lighter as the starch percentage increased. Then the mechanical properties such as hardness and roughness properties were determined by using Shore Durometer and Hand-held Roughness Tester respectively. Both hardness and roughness properties were found to increase linearly with increasing starch concentration up to 30 wt%. The presence of tapioca starch in PP was found to have positive effect to the hardness and roughness properties. Next, the tribology properties of coefficient of friction (COF) and wear rate were determined with a computerized pin-on-disc wear and friction tester at dry sliding condition. 3D Non-Contact Profilometer also were used to measure the wear scar diameter and wear depth. It was observed that higher starch percentage in PP, lowered the average COF of the composite under dry conditions however the COF increased rapidly at 30 wt% of starch. As for specific wear rate, the result cames up to decreased when the starch percentage increased. Microstructure analysis has been utilized to support the discussion of the output. The results showed that, the addition of tapioca starch into PP matrix increased the wear resistance by decreasing the wear rate by 14.17% and reduced the COF by 20.67%.

ABSTRAK

Tujuan utama kajian ini ialah untuk mengkaji sifat geseran dan kehausan komposit matrik polimer yang dibuat daripada kanji ubi kayu selain menyediakan pada peratusan kanji yang berbeza dan mencirikannya. Polypropylene (PP) yang dicampurkan kanji ubi kayu telah disediakan menggunakan Mesin Tekanan Panas dalam peratusan kanji antaranya 0%, 10%, 20% and 30% isi kanji. Hasil daripada penyediaan sampel menunjukkan bahawa warna sampel yang terbentuk akan lebih cerah apabila peratusan kanji meningkat. Kemudian, sifat-sifat mekanik seperti kekerasan dan kekasaran ditentukan dengan menggunakan Shore Durometer dan Penguji Kekasaran Mudah Alih. Kedua-dua sifat ini didapati bertambah secara linear dengan peningkatan peratusan kanji sehingga 30%. Kehadiran kanji ubi dalam PP didapati mempunyai kesan positif terhadap sifat kekerasan dan kekasaran. Seterusnya, sifat tribologi pekali geseran dan kadar kehausan ditentukan dengan menggunakan pin-pada-cakera berkomputer pada keadaan geser kering. Profilometer 3D juga digunakan untuk mengukur diameter parut kehausan dan kedalaman kehausan. Telah diperhatikan bahawa peratusan kanji yang lebih tinggi dalam PP, telah menurunkan purata geseran pada keadaan kering namun geseran meningkat pesat pada 30% berat kanji. Bagi kadar haus, ia menurun apabila peratusan kanji meningkat. Analisis mikrostruktur telah digunakan untuk menyokong perbincangan. Keputusan menunjukkan bahawa, penambahan kanji ubi ke dalam matriks PP meningkatkan rintangan haus dengan menurunkan kadar haus sebanyak 14.17% dan mengurangkan geseran sebanyak 20.67%.

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LIST OF ABBREVIATION AND SYMBOLS

PP	-	Polypropylene
PMC	-	Polymer Matrix Composite
&	-	And
m	-	Meters
mm	-	Millimetres
g	-	Gram
cm	-	Centimetre
N	-	Newton
hr	-	Hour
min	-	Minute
sec	-	Second
℃	-	Degree Celcius
psi	-	Pound per Square Inch
%	-	Percentage
rpm	-	Revolution per Minute
in^3	-	Inch Cube
lb	-	Pound
ft	-	Feet
etc	-	Et Cetera
MPa	-	Mega Pasca
i.e	-	in example
wt%	-	Weight Percentage
^{o}	-	Degree

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CHAPTER 1

INTRODUCTION

1.1 Background

As well known, synthetic polymer materials have played an important role and have been extensively used in many applications of all fields for many years. Polypropylene is one of the synthetic polymer and basically they resistant to acids and alkaline plus high in tensile strength. Synthetic polymers basically famous for their high mechanical performances, good barrier properties, good heat seal ability and can be tailored easily (Jamshidian, Tehrany, Imran, Jacquot, & Desobry, 2010). However, unfortunately they are quite expensive. Besides, they are all non-biodegradable and manufactured from non-renewable resources. Thus, man focused on biopolymer that tends to be biodegradability and low cost.

In order to solve the non-biodegradable issues, the demand on biodegradable polymers called biopolymers have raised. The word biodegradable means that the degradation of a polymer in natural environment that includes changes in chemical structure, loss of mechanical and structural properties and finally changing into other compound like water, carbon dioxide, minerals and intermediate products like biomass and humid materials (Jamshidian et al., 2010). Starch is one of the biopolymers or natural polymer and own many compromising properties in developing sustainable materials which are biodegradability, low cost, renewability, natural, environmental friendly and can be modified easily (Lu, Xiao, & Xu, 2009). However, starch itself is sensitive to water and cause the starch to have some limitations. The starch-made materials will swell and deform upon exposure to moisture.

Thus, starch often blended with synthetic polymers to improve its properties, biodegradability and to minimize the usage of synthetic polymer (Siang, 2012).

The study of properties of polymer composites matrix (PMC) is very important. This is because different type of PMCs provides different kind of properties in mechanical behaviour, friction and wear. These situations can be due to various combinations or mixtures, the temperature, types of presence microorganism and also the concentration of blend polymers. Therefore, this study will focus on the blend of polypropylene (PP) and tapioca starch with different concentration to investigate their friction and wear properties. The result of this study will provide the better blend concentration in order to discover friction and wear properties of this type of PMC for future use.

1.2 Problem Statement

Polypropylene is an expensive and a non-biodegradable polymer while starch is lower cost but have it limitations mainly due to the very sensitive to relative humidity and solubility in water. In order to overcome these challenges, several researches have successfully blend the starch with synthetic polymer to improve their mechanical properties. However, there is no yet a research on friction and wear properties of PP blend with tapioca starch. Therefore, the effect of the PP blend with the degradation of tapioca starch on friction and wear behaviour is remains unknown. Thus, this study is focused on PP blend with tapioca starch at different concentrations to achieve desired mechanical properties, friction and wear and to design a lower cost PMC.

1.3 Objectives

The objective of this study are;

i. To investigate the effect of starch concentration in polymer matrix composite (PMC) on friction and wear properties

1.4 Scope

The scope of this study are:

i. The polymer used in this study are tapioca starch and PP only

ii. This study only focus on wear and friction properties of PMC using tapioca starch

iii. The polypropylene blend with tapioca starch at different concentration which are 10%, 20%, 30% starch concentrations and neat PP

iv. The sliding condition for the friction and wear test is under dry condition.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Polypropylene (PP)

Polypropylene (PP) is one of the types of thermoplastic polymer that is used widely in a range of function such as packaging, textiles, stationary, equipment and automotive components. PP is a synthetic polymer that offers an outstanding physical, mechanical, thermal and chemical properties that not found in other thermoplastic polymers (Pérezr, Rivas, & Rodríguez-Llamazares, 2013). Based on Handbook of Polypropylene and Polypropylene Composites (2nd Edition), during the period from 1974 to 1999, the percentage of usage of PP increased from 7% to 12% by the year. This increasing of PP usage required the production to keep up with the increasing demand. Many years passed yet there is always a research in improving PP itself and its properties so that it can meet up with the increasing demand in market.

PP is produced from olefin or alkene monomers that contain a reactive carbon to carbon double bond. The PP started with a monomers called Propylene thus the final product which consist thousands of Propylene monomers is called Polypropylene. Figure 2.1 shows the molecular structure of PP (Calhoun, 2009).

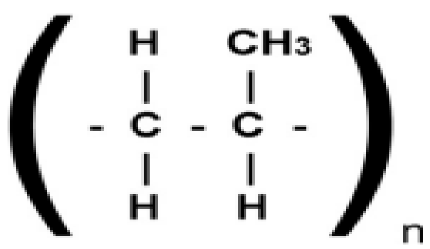

Figure 2.1: Monomer Unit of PP (Calhoun, 2009)

2.1.1 Application of Polypropylene

PP for ages has been developed for many usages over and over again. Now, the major markets for PP are dominated by rigid and flexible packaging which is 37%, followed by automotive compartments, electric and electronic parts and appliances (21%) and textile applications (18%) (Syazwan, 2010).

2.2 Introduction to Starch

Starch is the leading storage component in multiple plants, is important in energy source for developed seedling and is also valuable resources for food and non-food industries due to its exclusive structure-forming behaviours (Molenda et al., 2006). Starch is the natural biopolymers that broadly used to develop environmental-friendly packaging materials to replace petrochemical-base plastic materials. The main source of starch are corn (82%), wheat (8%), potatoes (5%) and cassava derived from tapioca starch (5%) (Kamel & Alwaan, 2018). Figure 2.2 shows the glucose monomer units with two important groups, the –OH and C-O-C bond that made up a starch molecule as a semi-crystalline polymer (sM.K Oduola, 2015).

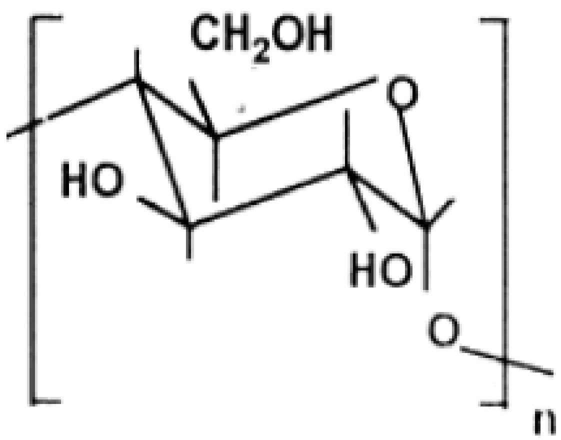

Figure 2.2: Starch Structure (M.K Oduola, 2015)

Starch is not a true thermoplastic but it can transformed into a plastic-like called thermoplastic starch (TPS) (Mitra, 2014). Starch has been received growing attention as promising fillers since the past four decades for its good biodegradability, low cost and renewability (Henry Chinedu Obasi, Ogbobe, & Madufor, 2015). TPS is a renewable and flexible that can be easily used in different 6illime-plastification processes include injection molding, compression molding and extrusion blow molding with equipment used in manufacturing synthetic polymers (Nafchi, Moradpour, Saeidi, & Alias, 2013). According to M.K Oduola (2015), the starch that was mixed with other renewable and non-renewable thermoplastic can have excellent mechanical behaviours and decreased the cost of the materials.

2.3 Introduction to Composite

The composite matrix have been exist since Old Stone age (Elsevier Inc., 2017). Basically composites divided into three types of materials with different performance chemical and mechanically. The composites include Polymer Matrix Composites (PMCs), Ceramic Matrix Composites (CMCs) and Metal Matrix Composites (MMCs). However, this study only discussed on Polymer Matrix Composites (PMCs).

Composite has been defined as a multi-phase system that consisted of two or more matrix components and the reinforcement components. There are three phase of composite materials which are matrix, reinforcement and composite interface. Matrix component is a continuous stage that is included CMC, PMC and MMC by the different matrix materials while reinforcement is a single phase that scattered and surrounded by matrix which is usually fibrous materials (i.e glass fiber, organic fiber and so on)(Wang, Zheng, & Zheng, 2011). Composites interface is defined as an interface between the matrix and reinforcement phase.

2.3.1 Polymer Matrix Composite (PMC)

Generally, PMCs or sometimes called fiber-reinforced plastics are the composites matrix where the matrix is a polymer and the reinforcements or fillers are glass, carbon, boron or natural fibers. Polymer matrix composite (PMC) is a composite materials that contained many fibers that bound together by an organic polymer matrix. The PMC is designed so that the mechanical loads that applied to the material is being supported by reinforcements. The reinforcements in a PMCs provide strength and stiffness that are lacking in matrix while the function of matrix is to bond the fibers together to transfer loads between them (Herrmann, Stieglitz, Brauner, Peters, & Schiebel, 2013).

Polymer composites matrix began almost as soon as man had polymers and they became a part of polymer science and engineering. This is because people could make compositions and actively practise the mixing of every synthetic polymer with every other natural polymer in order to have the substantially and synergistic properties of materials. The properties are greater toughness and impact resistance, higher modulus and higher use temperature (Sperling, 2000). Other advantages of PMCs are their lightweight, high stiffness, high strength, good abrasion and corrosion resistance and also simple fabrication process. This shows excellent strength to wear resistance (Prashanthakuamr & Bhanuprakash, 2017). Thus, the PMCs is designed so that the mechanical loads that subjected in any structure are supported by the reinforcements. There are two major types of polymers used in matrix phase of PMCs which are thermoset and thermoplastics.

Thermoset polymers composed of long chains of molecules that are cross-linked to other chains of molecules included epoxies, polyimides, silicones, vinyl esters and unsaturated polyesters. At room temperature, these polymers can be either liquids or solids and soften when heated and cure (Elsevier Inc., 2017). Thermosets can lower the viscosity which eases wetting (Mitra, 2014). Thermosets, because of their cross-linked structure, tend to have excellent dimensional stability, high-temperature resistance and high resistance to solvents (Herrmann et al., 2013).

Thermoplastic polymers are not cross-linked but composed of long polymer chains that are entangled resulted of monomers units joined together (Askeland and Wright, 2013). Unlike thermoset, thermoplastic soften when heated but then harden again after cooling process. Examples of thermoplastic include polypropylene, polyethylene, polystyrene, poly vinyl chloride (PVC) and polyacetal and etc (Murphy, 1998). Unlike thermosets, thermoplastics are resistance to cracking and impact damage and recently thermoplastics have been developed high performance which have excellent high temperature strength and solvent resistance (Herrmann et al., 2013). Thus these offers thermoplastics a great promise for future manufacturing industry. Figure 2.3 shows the comparison of behaviours of thermosets and thermoplastic matrix.

Resin type	Process temperature	Process time	Use temperature	Solvent resistance	Toughness
Thermoset........................	Low	High	High	High	Low
Toughened thermoset..............	↑	↓	↑	↑	↓
Lightly crosslinked thermoplastic.....					
Thermoplastic......................	High	Low	Low	Low	High

Figure 2.3: Properties of Thermoset and Thermoplastic Matrix (Herman,2014)

2.3.2 Fiber Reinforcement

Function of reinforcing materials in Fiber Reinforcement Composite (FRC) is to increase the mechanical properties of the resin such as strength and stiffness. Currently, the most important fibers used are glass, aramid and graphite, and the organic fibers include polyethylene also becoming important. Glass fibers are the most widely used for high volume PMC applications since its tensile strength is competitive and cost is lower. The other fibers be used only when the stiffness or weight are at premium because glass has a relatively low stiffness. Natural fiber composite has such properties as low density, good thermal insulation, unlimited availability and low cost. Besides, the machine wear and procession equipment damage for natural fiber is lower compare to conventional synthetic fibers (Singh & Bhaskar, 2013). Thus, natural fiber composite is developed as an alternative to synthetic fiber as reinforcing materials in thermoplastics. Figure 2.4 shows the examples of natural fiber used as reinforcing materials in a composite.

Figure 2.4: Types of Natural Fibers (Udhayasankar & Karthikeyan, 2015)