EFFECT OF MATRIX DUCTILITY ON THE PROPERTIES OF PINEAPPLE LEAF FIBRE (PALF) REINFORCED POLY LACTIC ACID (PLA) COMPOSITE

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

by

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2019

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **EFFECT OF MATRIX DUCTILITY ON THE PROPERTIES OF PINEAPPLE LEAF FIBRE REINFORCED POLY LACTIC ACID COMPOSITE**

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

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I hereby, declared this report entitled "Effect of Matrix Ductility on the Properties Of Pineapple Leaf Fibre Reinforced Poly Lactic Acid Composite" is the result of my own research except as cited in references.

Signature : ....

Author's Name : EFFI NUR SHAZLEEN BINTI SALLEH

Date : 3 June 2019

APPROVAL

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

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ABSTRAK

Sehingga kini, terdapat pelbagai pengetahuan dalam kesusasteraan mengenai perkembangan biokomposit. Walau bagaimanapun, beberapa batasan utama adalah kerapuhan biokomposit apabila menggunakan matrik PLA yang membawa kepada sifat mekanikal yang kurang baik biokomposit. Oleh itu, matlamat utama projek penyelidikan ini adalah (i) meningkatkan kemuluran matrik PLA dengan penggabungan dengan PBS, (ii) menghubungkan analisis morpologi dengan sifat mekanik dan (iii) untuk membandingkan kesan-kesan kemuluran matriks ke atas biokompositif berasaskan PALF . Kandungan PBS disimpan sebanyak 5, 10,15 dan 20% di dalam pencampuran PLA / PBS dengan menyesuaikan kaedah *solvent casting*. Filem nipis kemudian dimampatkan dibentuk pada 175°C. Berikut ini, biokomposit dicirikan dari segi sifat tegangan dan morfologi patah permukaan. Dengan penambahan kandungan PBS, kemuluran gabungan itu bertambah baik daripada hanya 1.92% menjadi lebih daripada 4%. Pada masa yang sama, kekuatan tegangan campuran semakin berkurang apabila PLA dikurangkan. Begitu juga dengan modulus keanjalan di mana kekakuannya kurang apabila kandungan PBS meningkat. Walau bagaimanapun, tegangan dan pemanjangan pada sifat pecah telah dioptimumkan pada campuran 80/20, mungkin disebabkan oleh ketidakcocokan campuran. Campuran kandungan yang optimum, 80/20 kemudian digunakan dalam 40% PALF bertetulang PLA / PBS komposit. Komposit disediakan dengan menggabungkan teknik pra-preg dan membentuk mampatan. Dengan penambahan PBS dalam matriks PLA, kekuatan tegangan menurun dari 122 MPa hingga 102 MPa. Ini disebabkan oleh kekuatan tegangan yang lebih rendah daripada PBS mulur. Walau bagaimanapun, kerapuhan komposit bertambah lebih baik dengan pemanjangan ketika putus meningkat daripada 6.64 kepada 7.23%.

ABSTRACT

To-date, there is a large body of knowledge in the literature on the development of biocomposites. Nonetheless, some of the main limitation is the brittleness of the biocomposites when using PLA matrix which lead to relatively poor mechanical performance of the biocomposites. Thus, the main objectives of this research project are (i) improve the ductility of the PLA matrix by blending with PBS, (ii) correlate the morpological analysis with mechanical properties and (iii) to compare the effects of matrix ductility onto PALF based biocomposites. PBS content were kept at 5, 10,15 and 20% in PLA/PBS blending mixing by adapting solvent casting method. The thin film then were compressed moulded at 175°C. Following these, the biocomposites were characterized in terms of their tensile properties and surface fracture morphology. With addition of PBS contents, the ductility of the blend was improved from only 1.92% into more than 4%. At the same time, the tensile strength of the blends was decreasing as the PLA was reduced. Same goes to the modulus of elasticity in which the stiffness was lesser once the PBS contents was increased. However, the tensile and elongation at break properties were optimized at 80/20 blends, probably caused by the immiscibility of the blend. The optimum blends content, 80/20 were then utilized in 40 wt.% PALF reinforced PLA/PBS composite. The composite were prepared by combining the pre-preg technique and compression moulding. With addition of the PBS in the PLA matrix, the tensile strength were reduce from 122 MPa to 102 MPa. This is due to inferior tensile strength of the ductile PBS. However, the brittleness of the composite had improved with elongation at break increased from 6.64 to 7.23%.

DEDICATION

To my dearest Babah, Salleh Bin Hj. Masri,
my beloved Mama, Saparidah Binti Haris,
my supportive supervisor, Dr Zaleha Binti Mustafa,
my siblings, friends and families,
Thank you for the supports that I have been received, morally and financially and I am so grateful for all the prayers and understanding while I am doing this Final Year Project I and II.

ACKNOWLEDGEMENT

In the Name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I managed to complete the first stage of the final year project successfully.

I would like to convey my gratefulness towards my respected supervisor, Dr. Zaleha Binti Mustafa for all the advice and the endless support that have been given to me throughout the project. Thank you for the guidance as well as for giving me this golden opportunity to work on this project.

I would like to express my gratitude to all my friends for always giving me hands while I am in need and to always motivate me physically and mentally while I am working on completing this FYP I and II, especially those who always helping me in giving the advice and critics for the crucial parts in order for me able to improve my works.

Finally, a thank you from me for everyone who was important to this final year project report 1 & 2, and I sincerely apologize for not being able to mention everyone's names.

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PLA	-	Poly Lactic Acid
PBS	-	Polybutylene Succinate
PALF	-	Pineapple Leaf Fibre
KF	-	Kenaf
WF	-	Wood flour
PP	-	Polypropylene
PE	-	Polyethylene
PS	-	Polystrene
PET	-	Poly (Ethylene Terephthalate)
PVC	-	Poly (Vinyl Chloride)
PBAT	-	Polybutylene adipate terephthalate
MOE	-	Modulus of Elasticity

LIST OF SYMBOLS

Wt.%	-	Weight Percentage
Vol.%	-	Volume Percentage
MPa	-	Mega Pascal
GPa	-	Giga Pascal
°C	-	Degree Celcius
J/g	-	Joule per Gram
%	-	Percentage
mm	-	Millimeter
cm	-	Centimeter
T_m	-	Melting Temperature
T_g	-	Glass Transition Temperature
T_c	-	Cold Crystallization Temperature
X_c	-	Crystallinity

CHAPTER 1
INTRODUCTION

1.1 Research Background

First and foremost, polymers are obviously one of the most high demand materials in the industry these days. Polymer material has been used widely especially in the plastics industry ever since 1986 by Parkes that was a nitrocellulose-based plastic. The industrial polymers are going through a rapid growth for their synthetic polymers and the common usage in biomedical applications. The examples of synthetic polymers are polystyrene (PS), polypropylene (PP), polyvinyl chloride (PVC), nylon and Thermoplastic polyurethanes (TPU). Polymers are the basis of important industrial goods (Leiden, 2008).

Plastics somehow are non-biodegradable materials as they cannot be decomposed by any organisms for them being unnatural products to the nature. Plastics also cause many other problems such as pollution, flammable and are dangerous to be burned. Hence, many current researches have been conducted solely in order to improve and enhance the properties of plastics to change them to be biodegradable even though some disadvantages are still can be found.

Meanwhile, composites are now being extensively used for their unique properties as composite material is made from the combination of two or more materials, improving some of the mechanical and chemical properties of the materials. Composites are also known as the alternative materials to replace other materials with so many advantages on it. Optimizing the consisting materials inside the composites can affect the properties. In a composite material, there are several factors that should be considered first which are its possible stiffness and strength for design (D. Hull, 1981).

It is common in the industry to always trying enhancing the properties of the composites mechanically especially for the biodegradable polymers which are reinforced by the natural fibres as composite as they are used widely in the automobile industry for the non-visible components. However, most of the mentioned composites consist of non-biodegradable polymers such as polypropylene and polyethylene. Hence, there are several studies that have been conducted in order to solve this issue by replacing the non-biodegradable polymers with the biodegradable polymers especially the polymers that can be extracted from the organic resources.

Therefore, the biodegradable polymers such as poly lactic acid (PLA) and polybutylene succinate (PBS) are selected in this topic as to obtain the sustainable manufacturing while enhancing the durability of the composites. The impact of these two polymers towards the product is studied for an excellent result to be achieved. PLA and PBS are commonly used in the case of making the plastics able to be decomposed. Deng et al. stated that melt blending of PBS with PLA would appear to be an ideal route for improving properties of these polymers because of their complementarity, which is by increasing the toughness of PLA and the stiffness of PBS.

As this research mainly focuses on the durability of the composites and a good sustainability, the PLA and PBS polymers are highly being prioritized in order to upgrade the durability. Blending process of these two biodegradable polymers leads to an ideal ductility so that every processes including the combination and comparison of the two materials such as Tensile Testing and Scanning Electron Microscopy (SEM).

1.2 Problem Statement

As stated, nowadays plastics are commonly used in the industry. The great properties of the plastics lead to the wide production of them. Plastics can be seen are being used everyday in form of the school equipment, packaging, water bottle, furniture and more daily basis products. Even so, a huge usage of plastics are worrying as they provide more harm than benefits. The waste from the plastics is not preferable and has to be prevented because of the non-biodegradable properties. The impact of plastic pollution through ingestion and entanglement of marine fauna, ranging from zooplankton to cetaceans, seabirds and marine reptiles, are well documented (Marcus *et al.* 2014).

Malaysia is one of the country that actively involved in the pineapple industry ever since 1998 until today. Pineapple plant is really familiar for its fruit purposes but not for its leaf which is also known as a fibre. By utilizing the pineapple leaf fibre (PALF), this may lead to the increase in its applications for the industry. The proper extraction and processing of PALF will make it able to develop its application in construction, mechanical, automotive, naval, aeronautical and space industries (Leo *et al.* 2015).

Thus, to avoid more plastics waste and to enhance the applications of the natural fibre which is PALF for the durability purposes, some materials are added to solve these problems. Consequently, there will be a usage of the mentioned poly lactic acid (PLA) and polybutylene succinate (PBS) as the suitable polymers for this research. PLA is a brittle polymer so it needs a medium to improve its brittleness. That is why it will be blended with the PBS polymer as the combination of these two polymers can improve the ductility of PLA.

By blending process, these polymers will be used as the matrix for the improved composites. The composites will consist PLA and PBS as the matrix and PALF as the fibre. The biocompatibility properties of PLA, PBS and PALF are also the reasons why these materials are selected. However, there is still limitation for composites where humidity problems occur. In any case, this research will also try to improve the composites with the humidity issues.

1.3 Objectives

The objectives are as stated :

1. To investigate the compositional effects of the PLA/PBS blends towards the mechanical properties.

2. To correlate the effects of the PLA/PBS blends with their morphological.

3. To compare the effects of matrix ductility in the PALF based composites.

1.4 Scope

The scope of this research is to optimize the composite design for an excellent sustainability and durability. The materials that will be used are selected from the green sources in which they are not harmful and mostly can be degraded and decomposed to the nature. The scopes are as below :-

1) The thermoplastics used in this research are poly lactic acid (PLA) and polybutylene succinate (PBS) while the PALF is used as a fibre with loading at 40 wt.% : 60 wt.% in which the 40 wt.% will be the PALF contents and another 60% is for the polymer matrix. The composition of the two thermoplastics will be investigated at 60% matrix : 100% PLA along with the ratios of PLA/PBS blends at 95/5, 90/10, 85/15, and 80/20.

2) In order to achieve an optimum blend of PLA and PBS, the tensile test will be conducted to investigate the effects on their mechanical properties, confirming there is an improvement in the ductility of blends. The SEM analysis is used to obtain the morphological properties of the blends, to study how the miscibility will affect the ductility of the products.

3) The last product, which is the composite of the PALF and PLA/PBS blends, will undergo the tensile test to see enhancement of the mechanical properties after the addition of PLA/PBS blends as the matrix.

1.5 Rational of Study

This research is really significant for reducing the plastics waste problems that the current industry has caused. Higher the production of plastics, higher pollution occur to environment. Living organisms especially the marine ones are in danger and there was unfortunate case happened in August 2015, where a sea turtle had its nose stuck with a plastic straw. This is one of the example on how the plastics pollution is really harmful to the living organisms.

Consequently, the study to prevent and to lessen the plastics issues needs to be done in order to save many lives and to make the earth always *go green*. The plastics problems is not something new until today and the actions that have been taken to calm things down are not in a small number. However, it is really important to solve things by correcting what is wrong and hence the usage of the biodegradable polymers for the industrial plastics are one of the solutions. Some of the examples are poly(lactic acid) (PLA), poly(glycolic acid) (PGA), starch-based blends and polybutylene succinate (PBS).

In this study, the poly lactic acid (PLA) and polybutylene succinate (PBS) are used to solve the stated cases. Other than the non-compostable issues, this research is also focuses on enhancing the durability of the composite while maintaining the sustainability in manufacturing of the product. Both biodegradable polymers are also the solutions for the durability of polymer. The tensile testing will be done on the combination of the two polymers later on to get the point where the toughness and ductility are ideal. Materials processes will be conducted too in order to get the surface of the polymers taken for the research data. This also increases the students' understanding and are able to learn how to get results taken from SEM, compression molding, tensile test and many other related processes.

1.6 Research methodology

In this section, the methodology is briefly listed as for the preparation for the processes that related to the research. Figure 1.1 shows the methods that are selected based on the relevant studies before. There are two stages in this study which are :

1) The stage to find an optimum blend

2) The fabrication of the composite

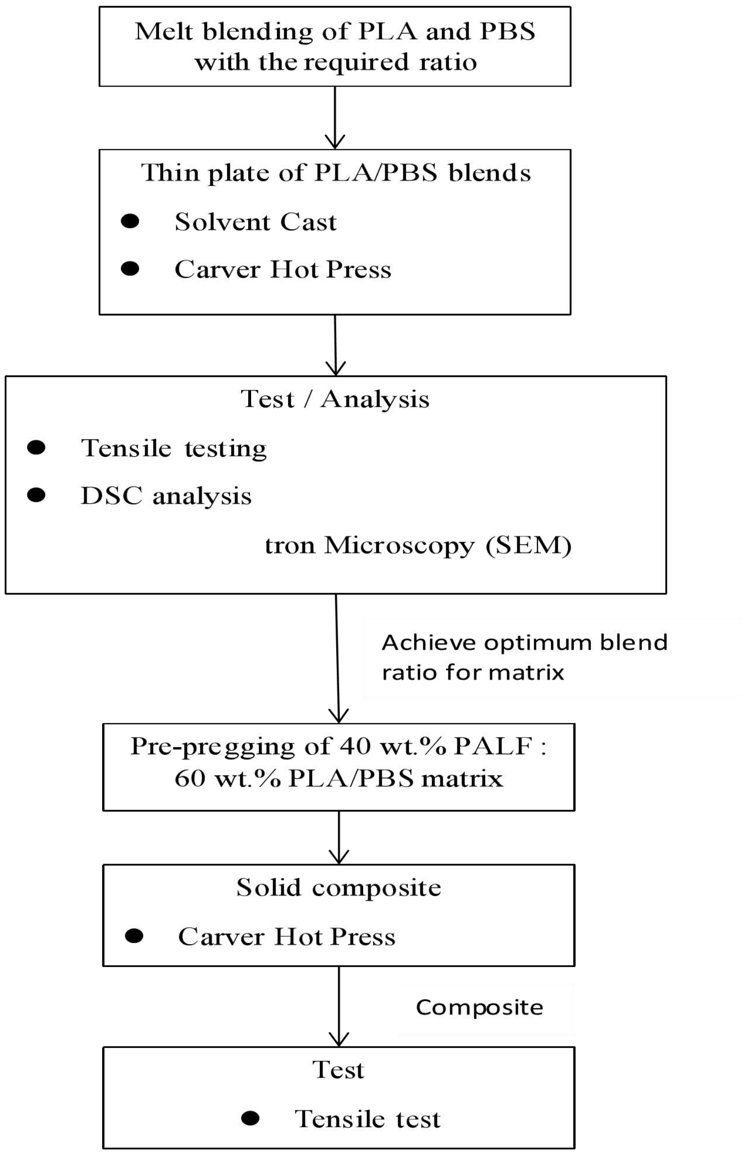

Figure 1.1 : Research methodology flow