UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF COMPOSITE MATERIAL FOR 3D PRINTING FILAMENT USING RECYCLED POLYETHYLENE TEREPHTHALATE (rPET) REINFORCED WITH SUGAR PALM FIBER (SPF)

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BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY WITH HONOURS

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Faculty of Mechanical and Manufacturing Engineering Technology

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A thesis submitted
in fulfillment of the requirements for the degree of
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2021

DECLARATION

I declare that this thesis entitled " Development of 3D Printing Filament Material Using Recycled Polyethylene Terephthalate Reinforced With Sugar Palm Fiber" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : A R I E F

Name : Muhammad Arief Izuddin bin Abdul Ghapar

Date : 18 January 2022

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Manufacturing Technology with Honours

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Date : 18 January 2022

DEDICATION

This report is dedicated to my parents, lecturers, and friends for their endless support and encouragement. And a very big thank you to my supervisor, Dr Nuzaimah binti Mustafa who has guided me from zero along way to finish my project. Thank you all for your endless support, and courage for me to finish this project

ABSTRACT

Environmental issues have led to various approach by researcher in producing alternative way to solve it. Thus, one effective way is to maximize utilization of natural fiber used as filler to be combine with thermoplastic material in 3D printing industries. In this study, a sugar palm fiber (SPF) was used as a filler material reinforced with recycled Polyethylene Terephthalate (rPET) to fabricate as composite for 3D filament printing. The aim of this study is to evaluate and characterize sugar palm fiber reinforced polyethylene on physical, morphological, and environmental properties. In this study, fiber loading was used 0, 1,3, and 5%. The preparation of sugar palm is the most important procedure to obtain suitable sugar palm particle size. Sugar palm fiber than were treated with sodium hydroxide with proper amount of concentration (6%) and soaking time (2 hours) to enhance the compatibility of fiber and the matrix. Additionally, fiber loading of composite was test for water absorption, SEM, and soil burial. In this study, degradation of sugar palm fiber and recycled polyethylene terephthalate was conducted using TGA. The purpose of TGA was to determine component that were degraded for sugar palm fiber and fraction of volatile component that degrade in recycled polyethylene terephthalate by monitoring the weight changes. The melting point and melt flow rate were observed by Differential scanning calorimetry (DSC) was conducted on rPET that later used for fabrication process. Hot press technique was used in this study to fabricate the composite. The result revealed that water absorption for treated fiber 5% exhibits maximum water uptake due to the good interfacial bonding between fiber and matrix. Morphological properties of water absorption and soil burial were conducted using SEM. The findings show surface of composite consists of voids, crack and fracture which attribute to water absorption. Soil burial test was conducted to evaluate the biodegradable properties of composite. The result shows that treated sugar palm composite exhibited highest degradability than untreated sugar palm composite. This may attribute to improved adhesion of sugar palm fiber through sodium hydroxide treatment. Overall, results indicated with treated sugar palm fiber can improves physical and environmental properties which proved that chemical treatment have improve surface adhesion of fiber and matrix.

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ABSTRAK

Baru-baru ini, ada banyak usaha untuk mengembangkan bahan mesra alam dan biodegredasi jadi untuk dikomposit ke arah penambaikkan yang dapat memiliki nilai yang lestari dan keuntungan. Peningkatan penggunaan serat semula jadi dalam pelbagai industri telah mendapat daya tarikan untuk memanfaatkan kelebihan serat terhadap industri percetakan 3D untuk menggunakan sumber semula jadi iaitu serat untuk digabungkan dengan termoplastik. Tujun utama kajian ini adalah untuk mengekaji dan mengklasifikasi sifat fizikal, alam semula jadi dan komposisi di antara gabungan serat kelapa sawit dan juga termoplastik menjadi komposit. Kajian ini telah menggunakan gabungan nisbah 0,1,3 dan 5% untuk fiber dan jug polimer . Penyediaan ataupun proses awal serat fiber merupakan elemen penting dalam mendapatkan saiz optimum untuk dijadikan komposit.Seterusnya, serat fiber akan dimodifikasi struktur asas fiber untuk tujuan mengikatan antara fiber dan juga polimer.Serat fiber akan direndam dalam larutan sodium hidroksida dengan kepekatan sebanyak 6 % selama dua jam. Seterusnya, ujian terhadap komposit akan dijalankan.Antara ujian yang akan dijalankan adalah kadar penyerapan air, SEM, dan juga kaedah tanaman untuk tujuan biodegradasi.Pada awalnya, fiber akan menjalani ujian termal untuk mengetahui sifat penguraian fiber ujian ini juga akan dijalankan pada polimer Seterusnya, ujian DSC akan dijalankan pada polimer untuk mengetahui kadar pengkristalan dan juga takat didih untuk polimer.Ujian ini bertujuan untuk mengetahui suhu yang akan digunakan untuk tujuan fabrikasi.Hasil kaji menunjukkan ujian penyerapan air komposit menunjukkan komposit 5%menunjukkan kadar serapan maksimum kerana ikatan diantara fiber dan polimer bagus. Sifat morfologi penyerapan air dan pengebumian tanah telah dijalankan menggunakan SEM. Dapatan kajian menunjukkan permukaan komposit terdiri daripada lompang, retak dan patah yang dikaitkan dengan penyerapan air. Ujian pengebumian tanah telah dijalankan untuk menilai sifat terbiodegradasi komposit. Hasilnya menunjukkan komposit kelapa sawit yang dirawat menunjukkan kebolehdegradasian yang paling tinggi berbanding komposit kelapa sawit yang tidak dirawat. Ini mungkin disebabkan oleh lekatan serat kelapa sawit yang lebih baik melalui rawatan natrium hidroksida. Secara keseluruhan, keputusan yang ditunjukkan dengan gentian kelapa sawit yang dirawat boleh meningkatkan sifat fizikal dan persekitaran yang membuktikan bahawa rawatan kimia telah meningkatkan lekatan permukaan gentian dan matriks.

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LIST OF SYMBOLS AND ABBREVIATIONS

SPF	-	Sugar palm fiber
NaOH	-	Sodium hydroxide
rPET	-	Recycled Polyethylene Terephthalate
TGA	-	Thermogravimetric
AM	-	Addictive Manufacturing
PLA	-	Polylactic Acid
ABS	-	Acrylonitrile butadiene styrene
CAD	-	Computer Aided Design
IV	-	Intrinsic Viscosity
PP	-	Polypropylene
MAPP	-	Maleic Anhydride Grafted Polypropylene
HDPE	-	High Density Polyethylene
PE	-	Polyethylene
wt.	-	Weightage
Wf	-	Weight final
Wi	-	Weight initial

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CHAPTER 1

INTRODUCTION

1.1 Background

Numerous pollutants, such as plastic waste created from petroleum-based polymers such as PET, are posing a significant hazard to the environment due to their non-biodegradable nature also PET waste is one of the least recycled types of plastic that keep discarded by human that can provoke serious problems to our ecosystem. Thus, recycling waste materials is one of the promising strategies for minimizing the environmental impact of these wastes while also minimizing natural resource depletion. Later in this research, the effect of sugar palm fiber incorporation in rPET will be examined.

Additive manufacturing (AM), or 3D printing, has been common technique for delivering product since the 1980s and is quickly becoming the quickest, the most direct approach to make custom products. AM is the overall term for creating a product layer-by-layer (Needham et al., 2013). Since then, it is become more favourable method among engineer and user compared with conventional engineering such as casting and machining which lack from precision and inconsistent and also one of the major problems which is waste of raw source that can easily be overcome by modern technique. AM can provide mass production, quality and can produce intricate geometry parts. Nowadays, the demand of 3D printing filaments has expanding rapidly due to its demand and sustainable alternative material for 3D printer filament are required to overcome environmental issues.

Sugar palm fiber as filler is not yet been recognised. Therefore, deep understanding of its properties and behaviour is important so that we can fully utilise it for manufacturing

development. Generally, the sugar palm fiber is currently being study and developed to it fully potential by most scientist and researcher. One of the most highlight points about the sugar palm fiber is the interface of the sugar palm itself when act as filler. Thus, one alternative and reliable source to approach this method are by proposing natural fibers such as sugar palm fiber as main material for the alternative by combine with waste consumer plastic such as polyethylene terephthalate (PET) to enhance it properties in thermo-stability, lightweight, strength, and transparency most important it can be reusable and recycle.

The purpose of this study, to innovate existing 3D printing filament by using natural fibers as material to improve modern technology into higher prospect. From this we will be able to maximize full potential of natural fibers especially sugar palm in few factors such as their physical properties and suitability of the fiber through modification which will utilize the characteristics of fiber in the research.

1.2 Problem Statement

Polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), are the most common material that were used in the 3D printing filament which both material has low fatigue resistance that will cause short lifespan for a product due to low stress that can be withstand without been fracture. In order to solve this problem polyethylene terephthalate were introduced as a main matrix for 3D printing filament as it has high resistance toward fatigue so it will improve life span of the product and have good strength.

Moreover, to overcome main problem occur in the polyethylene terephthalate which this material has poor resistance degradation compared to other thermoplastic this occur

when polymer changes its properties when exposed to temperature which tendency deform its shape, area, and volume. Therefore, by combining the matrix with the sugar palm fiber as a filler to over this issue.

Nowadays, usage of plastic was uncontrollably which lead to environmental issues such as climate changes, plastic pollution, landfill and many more this causes due to its non-biodegradable property, Thus by adding filler material

1.3 Research Objective

The main aim of this research is to develop a 3D filament material based on sugar palm fiber as reinforced material and recycled polyethylene terephthalate as matrix. The objectives of the research are as follows:

I. To characterize the sugar palm fiber and recycled polyethylene terephthalate for physical and thermal.

II. To evaluate the effect of sodium hydroxide treatment on sugar palm fiber thermal properties.

III. To evaluate physical and biodegradable properties of sugar palm fiber reinforced recycled polyethylene terephthalate.

1.4 Scope of Research

The scope of this research are as follows:

I. Testing and analyze morphological, biodegradable, physical and thermal of sugar palm fiber reinforced recycled polyethylene terephthalate.

II. Develop alternative material for composite based on combination of rPET and sugar palm fiber.

III. Material that used in this study is sugar palm fiber, recycled polyethylene terephthalate with fiber loading (0,1,3 and 5) wt.% and sodium hydroxide.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

3D printing is a process that allow us to create three-dimensional product or object through CAD modelling before sequentially layered the materials until the product or object were formed. 3D printing techniques were primarily used to construct functional or visual prototypes, a process known as fast prototyping. At the moment, the 3D printing market is expanding at a continuously and is likely to continue doing it far few years in future. 3D printing is being used innovatively in a wide variety of fields, including arts, construction, and medical devices (Ahmed et al., 2020).

Natural fibers have been increasingly popular as additions in extrusion-based filaments in recent years. Thermoplastic filament can be developed with aid from natural fiber that act as filler combined with polymer matrices. This can be done through various process such as compounding and fiber modification. The characterization of fiber should be study first and properly understand the nature of the fiber and their properties. After that, compounding process should be use of twin-screw extruder that enables scatter mixing for both fiber and matrices. Chemical treatment of fibers improves mechanical performance and has a beneficial effect on the load transfer capabilities of biofilter polymer interface. While fiber reinforcing appears practical and promising, it solve a number of problems, including the effect of fibers on resolution, agglomeration formation, heterogeneous composite production, printer head blockage, non-adhesion, and extended curing periods (Ahmed et al., 2020).

2.2 Natural fiber

Natural fiber was produced from plant, animal, and mineral based sources. In the past few years, researcher and scientist have discovered many alternative renewable resources that comes from biodegradable plant to overcome overuse of non-renewable resources due to its drawback that most of it will bring harm toward our ecosystem. Furthermore, due to it characteristic of fiber, which is light, cheap, and biodegradable become the main attraction for natural fiber to be alternative method compared to nonrenewable resources such as glass, plastic, and carbon fiber. However, natural fiber has its own weakness that comes from its hydrophilic nature which results in voids between the surface, thickness swelling this will lead to lack of mechanical properties of composite prepared from this natural fiber. To prevent this problem more research and technique utilization must be perform to improve high quality of natural fiber composite (Gholampour & Ozbakkaloglu, 2020).

2.2.1 Structure of natural fiber

One of the most important parameters that need to be understand is structure of sugar palm fiber. This parameter is very important as it is responsible for performance of the fiber composite. and important in enhancing future development in further research. The structural arrangement of sugar palm fiber is shown in Figure 2. **1** sugar palm fiber has a complex layered structure where outermost primary wall encloses to the secondary wall. The secondary wall consists of three-layer S1, S2 and S3. The middle layer is the thickest which cover 80 percent of the total the fiber thickness and responsible for mechanical properties of the fiber which also consists of cellulose microfibrils that are bound together by

amorphous lignin that acts as binder. Cellulose and lignin are most important component for the fiber as hemicellulose burnt out at an early stage of thermal analysis (Mukhtar, 2016).

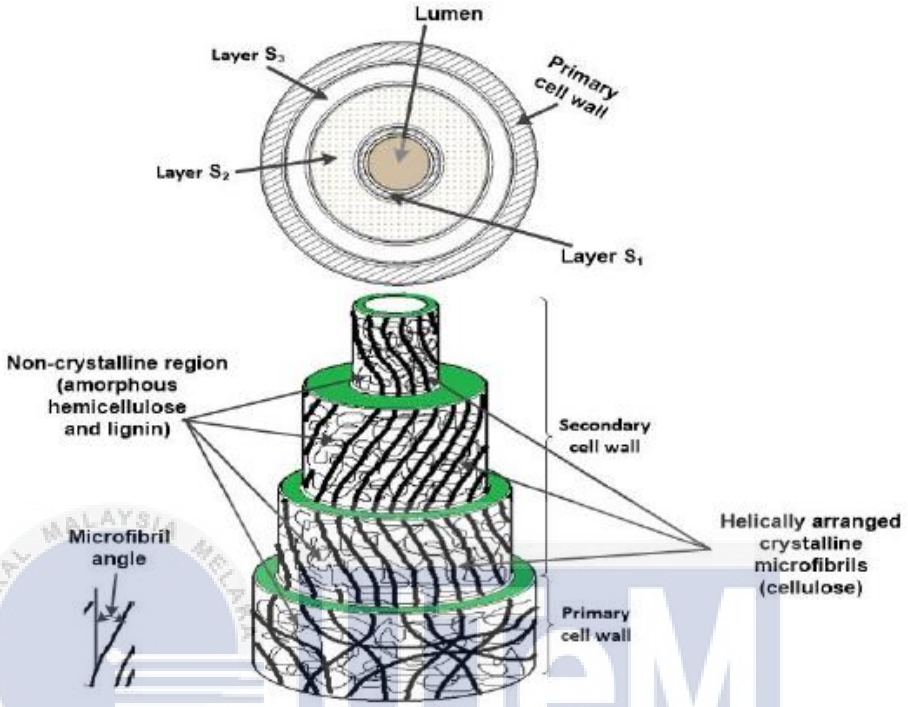

Figure 2. 1 Crossectional part of natural fiber

2.2.2 Types of natural fiber

Natural fiber can be classified into two types of fiber short fiber and long fiber usually short fiber are in range of 1- 5mm while long fiber is range from 5-50mm. Short fiber are fiber that usually comes from wood and non-wood species that most of them were used to make composites within plane isotropic properties which will produce composite with random fiber orientation. Long fiber typically comes from non-wood plant species such as flax, hemp and jute and usually used to composite that have anisotropic properties which have specific fiber orientation (Djafari Petroudy, 2017). There are also a few other types of natural fiber such as seed hair which is fiber that been collected from seed cases such as cotton, kapok, coir, and poplar seed. Bast fiber is a type of fiber that comes from bark of