DEVELOPMENT OF COMPOSITE MATERIAL FOR 3D PRINTING FILAMENT USING RECYCLED POLYETHYLENE TEREPHTHALATE (PET) REINFORCED WITH COCONUT FIBER

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in fulfilment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled “DEVELOPMENT OF COMPOSITE MATERIAL FOR 3D PRINTING FILAMENT USING RECYCLED POLYETHYLENE TEREPHTHALATE (PET) REINFORCED WITH COCONUT FIBER” is the result of my own research except as citied in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : MUHAMAD KHAIRUL AZRIN BIN CHE SEMAN

Date : 07/02/2022

APPROVAL

I hereby declare that I have checked this report entitled “DEVELOPMENT OF COMPOSITE MATERIAL FOR 3D PRINTING FILAMENT USING RECYCLED POLYETHYLENE TEREPHTHALATE (PET) REINFORCED WITH COCONUT FIBER” and in my opinion, this thesis it complies the partial fulfilment for awarding the award of the degree of Bachelor of Mechanical and Manufacturing Engineering Technology with Honours.

Signature : ....

Supervisor Name : *DR. YUSLIZA BINTI YUSUF*

Date : 07/02/2022

DEDICATION

All the praises and thanks to be to Allah S.W.T for His Love. I'm would love to dedicate this final report of my project to my father, Che Seman bin Che Soh and my mother, Che Asmat binti Hashim. The two persons that give me strength to be here during my studies. Special thanks to my supervisor and co-supervisor, Dr. Yusliza binti Yusuf and Dr. Nuzaimah binti Mustafa for the encouragement, constructive guidance, and patient in fulfilling my aspirations in completing this project. To my brothers, groupmates, and entire friends, will never achieve without all of you.

ABSTRACT

Recent years have seen a lot of interest in using natural Fiber composites. This is because they have a low density, are easy to get, and are cheap. The goal of this study is to find ways to make 3D printing filaments that are more environmentally friendly by using coconut fiber and recycled Polyethylene Terephthalate (PET), as well as how the Fiber weight ratio affects the properties of these filaments. The combined properties of coconut fiber and recycled polyethylene terephthalate as a new composite material will be examined to see whether it is acceptable for application in the area of 3D printing as a composite filler or filaments. The goal of this study is to figure out how coconut Fiber and recycled polyethylene terephthalate behave in terms of both physical and thermal properties. Second, to find out how sodium hydroxide (NaOH) treatment affects the thermal properties of coconut Fiber. The last goal of this study is to look at the physical, environmental, and morphological properties of recycled polyethylene terephthalate composites reinforced with coconut Fiber. The methodology used in this study is thermogravimetric analysis to determine the material's thermal degradation. The second test that will be used was scanning electron microscope (SEM) to study the surface of the material in size of micro. Additional tests for material characterization, such as water absorption test and soil burial, will be conducted as part of this study. However, based on the observations made on treated and untreated natural Fiber filaments during the testing and analysis, NaOH treatment may cause some degree of damage to the coconut fiber structure or surface, hence reducing the composite's mechanical capabilities.

ABSTRAK

Sejak tahun kebelakangan ini telah melihat banyak pengguna minat dalam menggunakan komposit Serat semulajadi. Ini kerana ia mempunyai ketumpatan yang rendah, mudah diperoleh dan murah. Matlamat kajian ini adalah untuk mencari cara untuk membuat filamen cetakan 3D yang lebih mesra alam dengan menggunakan gentian kelapa dan Polietilena Tereftalat (PET) kitar semula, serta bagaimana nisbah berat gentian mempengaruhi sifat filamen ini. Sifat gabungan gentian kelapa dan polietilena tereftalat kitar semula sebagai bahan komposit baharu akan diperiksa untuk melihat sama ada ia boleh diterima untuk aplikasi dalam bidang percetakan 3D sebagai pengisi komposit atau filamen. Matlamat kajian ini adalah untuk mengetahui bagaimana Serat kelapa dan polietilena tereftalat kitar semula berkelakuan dari segi sifat fizikal dan haba. Kedua, untuk mengetahui bagaimana rawatan natrium hidroksida (NaOH) mempengaruhi sifat terma Serat kelapa. Matlamat terakhir kajian ini adalah untuk melihat sifat fizikal, alam sekitar dan morfologi komposit polietilena tereftalat kitar semula yang diperkukuh dengan Serat kelapa. Metodologi yang digunakan dalam kajian ini ialah analisis termogravimetrik untuk menentukan kemerosotan haba bahan. Ujian kedua yang akan digunakan ialah "scanning electron microscope" (SEM) untuk mengkaji permukaan bahan dalam saiz mikro. Ujian tambahan untuk pencirian bahan, seperti ujian penyerapan air dan pengebumian tanah, akan dijalankan sebagai sebahagian daripada kajian ini. Walau bagaimanapun, berdasarkan pemerhatian yang dibuat ke atas filamen Gentian semulajadi yang dirawat dan tidak dirawat semasa ujian dan analisis, rawatan NaOH boleh menyebabkan beberapa tahap kerosakan pada struktur atau permukaan gentian kelapa, justeru mengurangkan keupayaan mekanikal komposit.

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LIST OF SYMBOLS AND ABBREVIATIONS

PET	-	Polyethylene Terephthalate
UPR	-	Unsaturated Resin
FTIR	-	Fourier Transform Infrared
FDM	-	Fused Deposition Modeling
ABS	-	Acrylonitrile Butadiene Styrene
PLA	-	Polylactic Acid
PVA	-	Plyvinyl Alcohol
TPU	-	Tensor Processing Unit
TPE	-	Thermoplastic Elastomers
PHA	-	Poly Hydroxy Acids
VOCs	-	Volatile Organic Compounds
PETG	-	Polyethylene terephthalate Glycol
NaOH	-	Sodium Hydroxide
TGA	-	Thermogravimetric Analysis
SEM	-	Scanning Electron Microscope
CAD	-	Computer-Aided Design

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CHAPTER 1

INTRODUCTION

1.1 Background

There have been several environmental problems due to the increased use of plastics and industrial waste. This has attracted researchers' attention who are seeking for innovative ways of solving the problem. Polyethylene Terephthalate (PET) is a flexible plastic for the production of films and bottles of packaging. PET is not a direct environmental hazard but might be seen as a pollutant substance owing to the increase of plastic trash and its strong atmospheric and biological resistance. As a consequence, PET recycling will not only reduce solid waste but also save raw petrochemical resources and energy. A few experiments were conducted for the combination of polyester with coconut Fiber to produce coconut composites. There is no research, however, of the use of coconut Fiber as a polyester reinforcement produced of recovered PET (Abdullah and Ahmad, 2013).

Coconut Fiber offers a number of advantages over other natural Fibers, including a high failure strain and increased weather resistance owing to the presence of lignin. Coconut Fiber absorbs less water due to its reduced cellulose concentration. Due to its broad and variable diameter, high microfibril angle, and high lignin and hemicellulose content, coconut Fiber, like other natural Fibers, is proven to be a poor reinforcement (Abdullah and Ahmad, 2013).

3D printing is a term that refers to a method of producing 3D objects quickly and easily from digital computer-aided design (CAD) data. The cost of 3D printers ranges from half a million dollars for direct metal laser sintering to hundreds of dollars for fused deposition manufacturing (FDM) machines. 3D printers today are capable of processing a wide range of materials and producing fully usable parts. Robotics, vehicle parts, weapons, medicine, space, and other applications have all been investigated using 3D printing technologies (Jason Lehrer, 2017).

The aim of this research is to develop the 3D printing filament material using recycled polyethylene terephthalate and the coconut fiber used as reinforced material.

1.2 Problem Statement

3D printing technology has opened up new possibilities for sectors, including quicker product creation, customisation, cost reduction, and tangible product testing. For example, its ideas are gaining traction in the medical and dentistry sectors, where personalization is essential. Firstly, Polyethylene terephthalate has become environmental threat to ecosystem. The most visible kind of pollution caused by plastic packaging is discarded plastic dumped in landfills. Because plastics are extremely stable, they remain in the environment for an extended period of time after they are disposed, even longer if they are protected from direct sunlight by being buried in landfills. Antioxidants, which are frequently added to containers to increase their resistance to attack by acidic contents, further slow decomposition rates. (Jason Lehrer, 2017).

Second, filaments are costly and may have limitation. The plastic filament used in the 3D printing equipment is not the strongest or toughest plastic available. It is not appropriate for applications requiring high levels of hardness and impact resistance. This may have an effect on the production usage of 3D printing machines owing to the need for components that do not match the user's requirements and expectations.

Additionally, recycled PET was used in this study. PET is a polyester-based material that combines excellent mechanical, electrical, and thermal properties with strong chemical resistance and dimensional stability. PET absorbs relatively little moisture and has excellent flow properties, making it an ideal material for watertight containers such as food and beverage storage. It is an excellent material for lightweight objects such as plants, isolated bottles, and containers (Abdullah and Ahmad, 2013).

1.3 Research Objective

The objectives of this project have been stated as below:

1. To characterize the physical and thermal properties of coconut fiber and recycled polyethylene terephthalate.
2. To evaluate the effect of sodium hydroxide treatment on the coconut fiber thermal properties.
3. To analyze the physical, environmental, and morphological properties of recycled polyethylene terephthalate composite reinforced with coconut fiber.

1.4 Scope of Research

The scope of this research are as follows:

1. Testing and analyze morphological, biodegradable, and thermal of coconut fiber.
2. Develop alternative material for composite based on combination of PET and coconut fiber.
3. Material that used in this study is coconut fiber, recycled polyethylene terephthalate with fiber loading (0,1,3 and 5) wt% and sodium hydroxide.

CHAPTER 2

LITERATURE REVIEW

2.1 Polyethylene Terephthalate

PET, or polyethylene terephthalate, is a thermoplastic aromatic semicrystalline polymer with a high glass transition temperature, excellent mechanical properties, and chemical resistance. PET also offers a few additional benefits, including a low cost, high transparency, and moderate recyclability. Due to these properties, PET is utilized in industrial applications such as Fibers, films, bottles, and engineering plastics. PET has been used to store a wide range of beverages, snacks, and other consumer products (Korivi, 2015).

This is the most common polymer used in the Fibers of clothing, beverage, and food containers. PET also has excellent mechanical characteristics (such as tensile and tear strength), heat seal ability, and barrier capabilities against, among other things, oxygen, carbon dioxide, anhydride, and aroma chemicals. Additionally, this polymeric resin is used to create thermoformed structures and composites incorporating glass Fiber (Mandal and Dey, 2019).

This chapter's first half covers many critical aspects of PET nanocomposite technology. The following sections discuss state-of-the-art technological advancements in a variety of PET nanocomposites. Each of these sections is devoted to a certain kind of nanofiller and contains information on manufacturing methods and characterization of property enhancements, among other things (Korivi, 2015).

2.1.1 PET Extrusion

The recyclable PET bottles were shredded using a custom bottle peeler and plastic-cutting shears. The bottles were torn into a ribbon before being cut into little, pellet-sized pieces. Due of the extruder's limitation of processing components up to a diameter of 5mm, the pieces were kept to that size. Due to the difficulty of extruding PET on its own, glycol was added to the PET bottles to create a viable filament. PETG pellets were found to be a method for adding glycol to PET plastic and enhancing material properties. Shredded PET was mixed with virgin PETG pellets in a 50-50 weight-percentage ratio. Prior to extrusion, the combination of PET and PETG polymers was heated in an oven to help in evaporating any excess moisture absorbed by the plastics. The oven was preheated at 100°C and the drying process took about two hours. Weighing the plastic before and after the drying process allowed us to calculate how much moisture was removed. To avoid reabsorbing moisture prior to extrusion, the plastic mixture was extruded on the same day as the drying process. Due to a difference in melting temperature, the PET and PETG polymers were extruded at a higher temperature of 245°C (Jason Lehrer, 2017).

2.1.2 Application of Polyethylene Terephthalate

The most of PET production is used to make synthetic Fibers (more than 60%), with bottle manufacturing accounting for approximately 30% of global demand. PET's capacity to generate a broad range of grades with a wide range of molecular weights in a single polymerization unit is one of the primary reasons for its widespread usage. PET is a thermoplastic material that is available in two varieties: amorphous (transparent) and semi-crystalline (opaque and white). It may be manufactured as a resin, a film, or a Fiber. PET is robust, ductile, stiff, and hard in semi-crystalline form, while amorphous PET is more ductile. PET is very simple to recycle and may be broken down into its monomers for use in various applications (Jankauskaitė, Macijauskas and Lygaitis, 2008).

PET woven fabrics Polyester textiles may have a synthetic feel when compared to natural-fiber materials. Polyester, on the other hand, is more wrinkle resistant and is commonly blended with natural Fibers such as cotton and wool to create textiles with mixed properties. Polyester is the world's most frequently used synthetic material. Filament yarns are used in a wide variety of applications, including clothing, furniture, tyre cord, and technological textiles. Staple Fibers are used to knit and weave textiles for clothing and furnishings, including bed sheets, bedspreads, curtains, and draperies. Polyester fiberfill may be used to stuff pillows and cushion cushioning (Li-Na, 2013).

PET bottles PET has dominated the bottled water industry because to its excellent clarity and absence of flavour. PET exhibits excellent oxygen and carbon dioxide barrier properties. It was suitable for food packaging due to its chemical inertness and physical properties, notably in beverages and drinking water. Indeed, PET packaging combines high gas barrier properties necessary for carbonation retention with glass-like clarity, low weight, and recyclability. Additionally, it is used to manufacture bottles for cooking and salad oils, sauces, and dressings, as well as more specialised industries like as sports drinks and fruit juices (Li-Na, 2013).

PET film is a thermoplastic material that is frequently referred to as polyester film. As with other thermoplastics, PET films can be bubble extruded or biaxially oriented. Polyester film is one of the most often utilised substrates in the converting industry due to its balance of properties in contrast to other thermoplastic polymers (Li-Na, 2013).

2.1.3 Advantages and Disadvantage of Polyethylene Terephthalate

The benefit PET is a great material for 3D printing. It is a robust and flexible substance with a high success rate for 3D printed prototypes. It is ideal for things that require both flexibility and durability, such as mechanical components or electrical equipment casings. While many businesses prefer the latter materials for 3D printing, PET has a reputation for releasing less odour than other typical 3D printing materials such as ABS or PLA. PET is easily injection moulded and is frequently available in pellet form for this purpose. PET must be dried before to use in a moulding machine because to its hygroscopic nature. PET shrinkage is extremely low (less than 1%), although it varies according to a variety of parameters, including holding pressure, holding duration, melt temperature, mould wall thickness, and mould temperature, as well as the amount and kind of additives (Gironi and Piemonte, 2011).

The drawback is that polyethylene terephthalate is prone to oxidation. For example, it is not generally used for storing beer or wine since the shelf life of these beverages is believed to be long enough that some flavour deterioration may occur prior to consumption. PET is a non-biodegradable material, which is both beneficial and harmful depending on your perspective and intended usage. Polyethylene terephthalate is an excellent material in general. It contains a unique set of properties that make it particularly well-suited for consumer goods, notably textiles (Gironi and Piemonte, 2011).

2.1.4 Recycle of Polyethylene Terephthalate

Unsaturated polyester resin derived from polyethylene (PET) was synthesised as a matrix for the fabrication of coconut fiber/polyester composites. Glycolysis and polyesterisation of PET waste resulted in the formation of an unsaturated resin composition (UPR). A Fourier Transform Infrared (FTIR) analysis of the glycolysis product and resin generated revealed that connections were established at saturated sites and a cross-link network was formed between an unsaturated polyester chain and styrene monomer. To enhance the adhesion of coconut Fiber to polyester resin, various concentrations of alkali, silane, and silane on alkalized Fiber were applied, and the best treatment concentration was determined. The influence of water absorption on the sorption characteristics of composites was investigated using immersion in distilled water at room temperature. The best surface treatment for coconut Fiber was 0.5 percent silane on 5% alkalized coconut fiber/polyester composites, which resulted in a significant improvement in tensile properties. Water absorption properties of treated Fiber composites were also shown to be lower when compared to untreated Fiber composites (Abdullah and Ahmad, 2013).

From this research, it can be stated that polyester reinforced coconut Fiber composites made from recycled polyethylene terephthalate (PET) waste have potential uses in the construction industry and car interior substrates (Abdullah and Ahmad, 2013).

2.2 Coconut Fiber

Coconut Fiber is a kind of natural Fiber produced from the unripe coconut husk. After steeping the coconut in hot saltwater, the Fibers are removed from the shell using a process similar to that used to extract jute Fiber. Each Fiber cell is thin and hollow, with strong cellulose walls, and is around 1 mm in length and 10–20 m in diameter. Raw coconut Fibers measure between 15 and 35 cm in length and have a diameter of 50 to 300 m. When they are young, a layer of lignin forms on their walls, hardening and yellowing them. Due to the rigidity of coconut Fiber, it is utilised in products such as floor mats, doormats, brushes, mattresses with a coarse filling content, and upholstery (hutten, 2007).