DEVELOPMENT OF NOVEL COMPOSITE MATERIAL USING RECYCLED POLYETHYLENE TEREPHTHALATE (rPET) REINFORCED WOOD DUST

MUHAMMAD KHAIRUL AMIN BIN SHAMSUDIN
B091810184

BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PROCESS AND TECHNOLOGY) WITH HONOURS

2022

Faculty of Mechanical and Manufacturing Engineering Technology

DEVELOPMENT OF NOVEL COMPOSITE MATERIAL USING RECYCLED POLYETHYLENE TEREPHTHALATE (rPET) REINFORCED WOOD DUST

Muhammad Khairul Amin Bin Shamsudin

Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours

2022

DEVELOPMENT OF NOVEL COMPOSITE MATERIAL USING RECYCLED POLYETHYLENE TEREPHTHALATE (rPET) REINFORCED WOOD DUST

MUHAMMAD KHAIRUL AMIN BIN SHAMSUDIN

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this thesis entitled "Development Of Novel Composite Using Recycled Polyethylene Terephthalate (rPET) Reinforced Wood Dust" is the result of my 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 : *Khairul Amin*

Name : Muhammad Khairul Amin Bin Shamsudin

Date : 17 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 Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

Signature : ....

Supervisor Name : Dr Nuzaimah bte Mustafa

....

Date : 18 January 2022

....

DR. NUZAIMAH BINTI MUSTAFA
Pensyarah
Jabatan Teknologi Kejuruteraan
Pembuatan Fakulti Teknologi Kejuruteraan
Mekanikal dan Pembuatan
Universiti Teknikal Malaysia Melaka

DEDICATION

I dedicate my dissertation work to my family and many friends. I owe a particular debt of appreciation to my devoted parents, Encik Shamsudin and Puan Hapsah, whose words of encouragement and push for tenacity ring in my ears. My sisters Irsyada and Syifa have never left my side and are extremely dear to me. This dissertation is also dedicated to my closest friend, Nina who helped me here and there throughout the process. This work is also dedicated to my closest laboratory buddy Arief and Azrin, who have been there with me from the beginning of this PSM, doing all the projects and tests. All of them are my biggest supporters.

ABSTRACT

There have been many developments in additive manufacturing technology in recent years. Still, only a few attempts have been made to use composite natural materials such as wood dust and recycled polyethylene terephthalate (rPET) for 3D printing. The initial findings of this research project aim to development of novel composite material using rPET reinforced wood dust. The objectives include characterizing the wood dust and rPET for physical and thermal properties, assessing the effect of sodium hydroxide treatment on the physical and morphological properties of wood dust-rPET composite, and evaluating the effect of fiber loading in the composite. This study was conducted in several laboratories owned by Universiti Teknikal Malaysia Melaka (UTeM). Furthermore, the method used to complete this project is by selecting raw materials such as rPET from matrix material and wood dust from natural fiber material. Wood dust have been identified in terms of properties and then treated using a chemical liquid sodium hydroxide (NaOH) at a value of 6%. In addition, it also has been identified that the effect of treatment given to wood dust can make the composite more rigid. The finding in general shows that wood dust and rPET can be used as filament materials on 3D printing machines. Past studies have also shown that composites between wood dust and other polymers can produce filaments for 3D printing. In conclusion, if rPET and wood dust is recycled and transformed into filament materials for 3D printing, it can contribute to environmental sustainability.

ABSTRAK

Terdapat banyak perkembangan dalam teknologi pembuatan aditif dalam beberapa tahun kebelakangan ini. Namun, hanya beberapa percubaan telah dibuat dengan menggunakan bahan semula jadi komposit seperti habuk kayu dan polietilena tereftalat (rPET) kitar semula untuk cetakan 3D. Penemuan awal projek penyelidikan ini bertujuan untuk membangunkan komposit menggunakan rPET diperkukuh dengan habuk kayu. Objektif termasuk mencirikan habuk kayu dan rPET untuk sifat fizikal dan haba, menilai kesan rawatan natrium hidroksida ke atas sifat fizikal dan morfologi komposit habuk kayu-rPET dan menilai kesan pemuatan gentian dalam komposit. Kajian ini dijalankan di beberapa makmal milik Universiti Teknikal Malaysia Melaka (UTeM). Tambahan pula, kaedah yang digunakan untuk menyiapkan projek ini ialah dengan memilih bahan mentah seperti rPET daripada bahan matriks dan habuk kayu daripada bahan gentian asli. Debu kayu hendaklah dikenal pasti dari segi sifat dan kemudian dirawat menggunakan cecair kimia natrium hidroksida (NaOH) pada nilai 6%. Selain itu, ia juga telah dikenal pasti bahawa kesan rawatan yang diberikan kepada habuk kayu boleh menjadikan komposit lebih tegar. Dapatan secara umum menunjukkan habuk kayu dan rPET boleh digunakan sebagai bahan filamen pada mesin pencetak 3D. Kajian lepas juga menunjukkan bahawa komposit antara habuk kayu dan polimer lain boleh menghasilkan filamen untuk percetakan 3D. Kesimpulannya, jika rPET dan habuk kayu dikitar semula dan diubah menjadi bahan filamen untuk percetakan 3D, ia boleh menyumbang kepada kelestarian alam sekitar.

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. All praise for Allah S.W.T for his grace and blessing that made my learning journey much more accessible. I want to extend my appreciation to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform.

I would like to give special thanks to my research supervisor, Dr Nuzaimah bte Mustafa, for supporting me through one of the most significant projects of my life with incredible patience, support, and guidance, this whole time with a constant smile on her face. She has been overwhelmingly helpful and such a pleasure to work with and her effort to help me complete this research project.

My sincere thank you goes to my family and my loved ones for the unconditional support, patience and words of encouragement they have given me during my entire learning period. I would also like to appreciate all the lecturers that have taught me in Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours throughout my whole study in the UTeM.

Finally, thank you to all the individual(s) who had provided me with the assistance, support and inspiration to embark on my study. Only God could repay all your kindness. May God bless you. Thank you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

rPET	-	Recycled Polyethylene Terephthalate
FDM	-	Fused deposition modeling
3D	-	Three-dimensional
FFF	-	Fused filament fabrication
°C	-	Degree celsius
F&B	-	Food & beverage
FDA	-	Food and drug administration
NaOH	-	Sodium hydroxide
%	-	Percentage
CO2	-	Carbon dioxide
SEM	-	Scanning electron microscopy
cm	-	Centimeter
MPa	-	Megapascal
kg/m3	-	Kilogram per cubic metre
DSC	-	Differential scanning calorimetry
TGA	-	Thermogravimetric
µm	-	Micron
dl/g	-	Deciliters per gram
PPM	-	Parts per million
Mm	-	Millimeter
g	-	Gram

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

In this new age of modern production, production and process industries have to face a significant challenge to eradicate as many defects as possible in the business term. Along with that, the environment-friendly period remains in focus. After seeing the challenge facing the modern manufacturing sector, most people understand the value of manufacturing industries.

The growth of the manufacturing industries can generate national growth through either the sales of their products or the service they provide. It would also impact their great job opportunities by providing a broad sector of local manufacturing industries to employees.

3D printing produces physical objects from a geometrical representation by successive materials. Nowadays, 3D printing technology has developed very rapidly worldwide, widely used for the production of any open source designs in agriculture, mass customization, automotive industry, healthcare, aviation industries and locomotive industry (Madhav et al., 2016).

Various 3D printing technologies have been developed with their functions. There is no debate about which technology or machine works better because each has a targeted application. Like any manufacturing process, 3D printing needs a mixture of high-quality materials to produce a device according to the specifications and quality to be used to the maximum (Nwogu et al., 2019).

Composites or functionally graded materials, metallic, ceramic, polymer and their combinations in the hybrid form can be used and produced in 3D printing technology. In terms of the production of polymer components, 3D printing technology is widely used, from prototypes to functional structures with complex geometries. Due to their low cost, low weight and processing flexibility, 3D printing polymer materials in conditions of a low melting point are widely used in the 3D printing industry (Shahrubudin et al., 2019).

Many types of wastes such as plastic waste derived from a petroleum-based polymer such as recycled PET (rPET) become a major threat to the environment due to their non-degradable property. Also, waste from natural sources such as natural fiber waste was also commonly dumped and burnt illegally leading to air pollution. rPET waste of post-consumer plastic is among the least recycled plastics. Meanwhile, wood dust is abundant in woodworking industries such as furniture factories (Kariz et al., 2015).

Therefore, recycling waste materials is one of the promising solutions to minimize the environmental impacts of this waste while minimizing the use of natural resources. This research will later investigate the effect of wood dust incorporation in the rPET on the thermal and morphological properties of the fabricated composites to be applied as 3D printer filament.

1.2 Problem statement

As already mentioned, among the problems faced now is the uncontrolled excess of plastic waste. So, it is important for the industrial sector that uses 3D printing to develop and expand 3D printing technology using plastic materials. PET is also widely used for advertising displays, packaging (retail and medical), and electronic insulation. PET has a wide range of applications that are often used in industry because of its resistance to heat, solvents and impacts (Sinicki, 2020).

3D printing technology has opened up new possibilities for sectors, including quicker product creation, customization, cost reduction, and tangible product testing. For example, its ideas are gaining traction in the medical and dentistry sectors, where personalization is essential. However, a few problems may affect 3D printing manufacturing, including plastic waste is often non-biodegradable, which means it can take hundreds of years to disintegrate. This is because plastics are composed of intermolecular connections and their structure protects them from rusting or dissolving. Plastics that are improperly disposed of becoming water reservoirs. They block rivers and float on the surface of lakes, contaminating and impeding their flow (Jason Lehrer, 2017).

Every creation has its shortcomings, so the problems that often occur to 3D printing machines include quality problems on the products produced. For example, there are many quality-related problems with 3D printing such as brittle FDM (unified deposition modeling) parts, low-resolution output and materials (Kowalski, 2015).

Due to the issue of increased waste production as a result of the usage of PET, it is necessary to seek other solutions. Chemical recycling is a viable process for converting non-renewable raw materials into a material with potential use in concrete additives, such as polyester resins with the following improvements, and conserving non-renewable raw materials may help decrease the environmental effects (Mendivil-escalante et al., 2014).

The cost of printed items is affected by the costs of materials used and the time it takes to be printed. Compared with other filaments, some filaments are costly, and the process of printing may place restrictions on their use. Filament costs can be decreased by using affordable filler materials that are natural fiber to be combined with polymer matrix, which can also improve their flexural rigidity, mechanical characteristics, and stability when solidified (Ahmed et al., 2020).

1.3 Research Objective

The aim of this research is to development of novel composite material using recycled polyethylene terephthalte (rPET) reinforced wood dust. Hence, the objectives are as follows:

a) To characterize the wood dust and rPET for physical and thermal properties.

b) To assess the effect of sodium hydroxide treatment on the physical and morphological properties of wood dust-rPET composite.

c) To evaluate the effect of fiber loading in the composite.

1.4 Scope of Research

To ensure that all project objectives are achieved, the following are few important elements that must be followed. The scopes of this research are as follows:

a) Material that used in this research was wood dust and rPET.

b) Treatment of wood dust using NaOH.

c) To test and analyse physical and thermal properties of wood dust.

d) To test thermal properties of rPET.

e) To study physical and morphological of the composite wood dust and rPET.

f) Material that used in this study was rPET and wood dust with fiber loading 0 %, 1 %, 3 % and 5 %.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter highlights the theory, knowledge, and findings of previous researches about the development of 3D printing filament by using recyclable waste mixed with wood dust by some analysis to compare whether the materials can become a filament to use in 3D printing machine.

2.2 3D printing

Nowadays, 3D printing technology has expanded very quickly and is expected to expand more in the global market in the next few years. Additive manufacturing techniques are rapidly grown in industrial and household environments because they have various exciting features that can be used. For example, suppose production is required on a small scale. In that case, parts can easily be obtained with limited scrap production and energy consumption without expensive tools or complicated installation. 3D printing techniques allow the manufacturer to create objects with complex shapes and suitable thicknesses, which is usually not achievable through standard polymer manufacturing methods (Mazzanti et al., 2019). Figure 2.1 shows the differences between traditional and additive manufacturing methods.