# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# EFFECT OF FIBER LOADING OF BIOCOMPOSITE FUSED FILAMENT FABRICATION

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering Technology (Product Design) with Honours.

by


**MUHAMAD LUTHFY BIN KASIM**

**B071610253**

**940707-06-5933**

FACULTY OF MECHANICAL AND MANUFACTURING ENGINEERING


2019

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA**

Tajuk: EFFECT OF FIBER LOADING OF BIOCOMPOSITE FUSED FILAMENT FABRICATION

Sesi Pengajian: 2019

Saya **MUHAMAD LUTHFY BIN KASIM** mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (X)

☐ SULIT* Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972.

☒ TERHAD* Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan.

☐ TIDAK TERHAD

| | |
|---|---|
| Yang benar, | Disahkan oleh penyelia: |
| ........................................................ | ........................................................................... |
| MUHAMAD LUTHFY BIN KASIM | DR.MASTURA BINTI MOHAMAD TAHA |
| Alamat Tetap: | Cop Rasmi Penyelia |
| LOT 1213, | |
| KAMPUNG KUALA LANAR, | |
| 27200 KULA LIPIS, | |
| PAHANG | |
| Tarikh: | Tarikh: |

*Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

## DECLARATION

I declare that this thesis entitled "Effect of fiber loading of biocompposite fused filament fabrication" 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 the candidature of any other degree.

Signature : .......................................................

Name : Muhamad Luthfy bin Kasim

Date : .......................................................

## APPROVAL

This report is submitted to the Faculty of Mechanical and Manufacturing Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Product Design) with Honours. The member of the supervisory is as follow

Signature :………………......... .................

Supervisor Name DR. MASTURA BINTI BOHAMAD TAHA

Date :…………………….........

# DEDICATION

In the name of Allah, the Most Gracious, the Most Merciful and all praises to the Prophet, Muhammad S.A.W. Alhamdulillah, praise to Allah for His mercy, I have successfully completed this project in a timely manner.

I would like to take this opportunity to extend my utmost gratitude and sincere appreciations, to my mother, ***Aini binti Mohamod*** for his support and sacrifice to confront with all problems and difficulties along this journey, mentally and physically.

May Allah rewards all of you with goodness and prosperity, here and hereafter

**_ABSTRAK_**

*Disebabkan isu-isu alam sekitar, dan penggunaan sumber yang boleh diperbaharui, pembangunan produk kejuruteraan berkualiti tinggi yang diperbuat daripada sumber asli berkembang pesat di seluruh dunia. Komposit adalah bahan terkini yang menggabungkan dua atau lebih bahan untuk mendapatkan sifat yang lebih unggul dibandingkan dengan komponen individu  Serat kenaf dirawat menggunakan rawatan kimia untuk meningkatkan kekuatan ikatan antara serat dan matriks.Oleh itu, kertas ini membentangkan tentang penghasilan filamen kenaf / ABS biokomposit yang dibuat untuk Fused Filament Fabrication atau pembuatan adiktif. Juga kesan pemuatan gentian Kenaf dan Acrylonitrile butadiene stirena (ABS) sebagai matriks pada sifat-sifat mekanikal bahan tersebut akan diselidik. Komposit disediakan dengan memasukkan teras inti kenaf pada muatan yang berlainan ke dalam matriks (ABS). Kertas kerja ini juga menilai kesan pengubahsuaian permukaan serat pada ciri-ciri serat kenaf, dan ciri-ciri mekanikal biokomposit.. Ujian mekanikal yang dilakukan dalam kajian ini adalah ujian tegangan dan lenturan menggunakan Universal Testing Machine. Hasilnya dianalisis dan dapat disimpulkan dengan semakin tinggi beban serat, semakin besar sifat mekanik biokomposit tersebut.*

**ABSTRACT**

Due to renewables and environmental issues, the development of high performance engineering products made of natural resources is growing worldwide. Composite is an advance material which combines two or more materials to possess superior properties compared to the individual component. Therefore, this paper presents the developments kenaf /ABS (Acrylonitrile butadiene styrene) biocomposite filament of Fused Filament Fabrication. Mechanical test (tensile test, flexural test and surface roughness) also applied to the biocomposite to determined their mechanical properties. The effects of Kenaf fiber loading and Acrylonitrile butadiene styrene (ABS) as a matrix on mechanical properties were studied. This paper also evaluated the impacts of fiber surface modification on kenaf fiber characteristics, and on biocomposite mechanical characteristics. The composites were prepared by incorporation of kenaf core powder at different loadings into (ABS) matrix. The kenaf fiber first was treated using a chemical treatment to improve the bonding strength between the fiber and the matrix. The fiber and ABS pallets then were mixed with AN internal mixture and the composite was extruded using and extruder to fabricate the biocomposite filament. Their results show there is an optimum fiber content to achieve the greatest mechanical properties of the biocomposite. As\ conclusion, the optimum fiber content between 5wt%, 7.5wt% and 10wt% is 7.5wt% as there is sufficient fiber content in the composite and does not create fiber agglomeration in the composite that can affect the mechanical properties.

## ACKNOWLEDGMENTS

Alhamdulillah, praise to god for His help and guidance that I am able to complete the task of this Bachelor Degree Project 1. I am thankful and grateful to my supervisor, Dr. Mastura binti Mohammad Taha for her advice and knowledge that she the in the completion of the project. I appreciate all those hands who help me and give me guidance in finishing the Bachelor Degree Project 1.

I also would like to thank all of my friends who have been really helpful and encouraging just to help me finish this project. A lot of ideas has been given by them for me to improve this project.

I am sincerely grateful to my parents for their love and their support for me throughout my life in all the activities that I have done. I also wanted to thank other people who have directly or indirectly help in the completion of my Bachelor Degree Project 1. I sincerely appreciate all your help.

## TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.0 Introduction

The first chapter discusses the introduction of the project. It includes the project background, problem statement, objective and work scope.

## 1.1 Background

This decade has seen excellent achievements in environmental and sustainability issues in the field of materials science by the development of biocomposite (Faruk et al., 2012). These problems led to the development of high-performance natural resources engineering products. In the last several decades, the application of natural fibers in composites has been increasingly concerning. These composites have numerous advantages over synthetic fibers, such as low wear, low density, lower cost and biodegradability.

The most commonly used natural plant are bast fibers, such as hemp, jute, flax, kenaf, and sisal (Raman Bharath et al., 2015) Natural fibers arise as low-cost and lightweight alternatives to composite fibers and appear to be environmentally inferior. The facts are that natural composites are environmental inferior to glass fiber composites are due to the lower environmental impact of natural fibers compared with the production of glass fiber. Natural fiber compounds have a greater level of fiber, thereby decreasing the pollution of the base polymer, In particular in automotive applications, light-weight natural fibers increase fuel efficiency and reduce emissions during component usage and the end of natural fiber-incineration will lead to energy and carbon recovery (Joshi et al., 2004).

The characteristics of a bio composite are affected by a variety of factors including the type of fiber, environmental conditions (where the fibers come from), methods of treatment and fiber modification. The requirements for the use of plastics as significant raw products have constantly risen in this decade, thermoplastics represent more than 80% of them. Bio fiber-reinforced plastic composites are more widely accepted for structural applications.

Extrusion deposition processes, such as fused deposition modelling (FDM), fusion filament fabrication and melt extrusion manufacturing (MEM) are among the most commonly used and quickly increasing fast prototyping and additive production (AM) technology (Turner et al., 2014). One of the most common AM technologies is extrusion-based processes. In addition, the fast-growing personal manufacturing market is dominated by the fused filament fabrication system, many based on the RepRap open source project (Jones et al., 2011). The Fused Deposition Modeling (FDM) process now holds the greatest market share of polymer AM processes. The dominant market for commercially based on extrusion systems is fused deposition modeling (FDM) devices from Stratasys, Inc. The market share of Stratasys for industrial AM devices in 2010 is 3.5 times that of any other system manufacturer, at 41.5% of all systems marketed according to Wohler in 2010 (Gardan et al., 2017).

## 1.2 Problem Statement

Despite the advantages of 3D printing such as freedom of design, customization and the capacity to print complicated constructions, there are a few drawbacks that would require further technological research and development. Due to renewable and environmental issues, the development of high-performance natural resource engineering products is increasing worldwide. Kenaf plants were used widely among the many different types of natural resources in recent years. In industrial applications, the major limitations of the use of fused deposit modeling (FDM) are the narrow range of available materials and parts fabricated by the FDM are used only as a demonstration or design parts rather than functional parts. Researchers have recently studied a number of ways to increase the range of materials available for the FDM process, thereby increasing the scope of FDM in different manufacturing sectors. The research is mostly focused on composite materials such as metal matrix composites, ceramic composites, natural fiber reinforced composites and polymer matrix composites (Mohan et al., 2017). The previous study has shown that their big variation of properties and characteristics represents the primary challenge in working with natural fibers. The characteristics of a bio composite are affected by a variety of factors including the type of fiber, environmental conditions (in which the plant fibers were produced), the processing method and the modification of the fiber. The purpose of this paper is to review research carried out so far in the development of natural fiber and polymer combination samples (Kenaf & ABS) based on their mechanical properties. This research also to examine the suitability of the bio composite as a filament for 3D printing.

## 1.3 Objective of study

The objective of this project are:

1) To develop treated natural fiber composite for Fused Filament Fabrication.
2) To investigate the mechanical properties of the treated natural fiber composite of Fused Filament Fabrication.

## 1.4 Scope of study

I. Kenaf fiber in the form of core powder.

II. Acrylonitrile butadiene styrene (ABS) as a matrix

III. Kenaf fiber will be degraded using Sieve Shaker machine, sieve size of 150 µm.

IV. The mixture of kenaf and ABS pallets based on kenaf fiber loading on 5wt%, 7.5wt%, 10wt%.

V. The mixture is put in a twin screw extruder, model HTGD- 20 (HARDEN INDUSTRIES LTD)

VI. The mechanical properties of the bio composite, commercialize ABS filament and ABS pallet will be tested.

# CHAPTER 2

# LITERATURE REVIEW

## 2.0 Introduction

Chapter 2 will be some discussion about the research background related to the project. This chapter also discusses the journals as references and examples from other sources linked to the project.

## 2.1 Biocomposite definition

Recently, there has been renewed interest in the reduction in harmful destruction of the ecosystem and to produce low cost polymeric reinforced composites, the researchers are emerging with policies of manufacturing the composites using natural fibers which are entirely biodegradable. These policies had generated safe strategies to protect our environment (Abdul Khalil et al., 2012). Over the last few years, polymers synthesized from natural resources have become a major focus of research. At the end of their lifetime, these bio-composites can be easily removed or composted without damaging the environment that synthetic polymer composites are not possible. The lignocellulose fiber, such as flax, hemp, kenaf, henequin, banana and oil palm as substitutes for synthetic fiber, such as glass and carbon. For many different uses, such as cars, aviation, packaging and construction sectors, natural fiber-reinforced bio composites have been used where elevated load capability is not needed. The natural fiber has a relatively high special strength, free formability, low self-weight and substantial resistance to corrosion and fatigue over the traditional counterparts (Gurunathan, Mohanty, & Nayak, 2015). The natural fibers have some unique qualities which are low cost, biodegradability, recyclability, an acceptable specific strength, easy to disassemble, low density, high thermal toughness, low wear of tools, skin irritation and improved energy recovery. The natural fibers are very cheap and promising compared to conventional synthetic fibers (Thakur, Thakur, & Gupta, 2014).

Table 2.1: Natural fiber classification, origin, global annual production and costs. (Bharath & Basavarajappa, 2016)

| Type of fiber (plant) | Botanical name | Origin | Production ($10^3$ ton) |
|---|---|---|---|
| Abaca | Musa textilis | Leaf | 91 |
| Bagasse | Saccharum officinarum L. | Stem | 102000 |
| Banana | Musa uluguruensis Warb. | Leaf | 200 |
| Bamboo | Gigantochloa scortechinii Dendrocalamus apus | Stem | 10000 |
| Coir | Cocos nucifera L. | Fruit | 650 |
| Cotton | Gossypium spp. | Seed | 19010 |
| Flax | Linum usitatissimum | Stem | 830 |
| Hemp | Cannabis sativa L. | Stem | 214 |
| Jute | Corchorus capsularis, Corchorus olitorius | Stem | 2850 |
| Kapok | Ceiba pentandra | Seed | 123 |
| Kenaf | Hibiscus cannabinus | Stem | 970 |
| Phormium | Phormium tenax | Leaf | - |
| Pineapple | Ananas comosus Merr. | leaf | - |
| Ramle | Boehmeria nivea Gaud | Stem | 100 |
| Sisal | Agave sisalana | Leaf | 318.8 |

Plants producing natural fibers are classified as primary and secondary according to their utilization. Primary plants are grown because of their fiber content, while secondary plants are the plants that produce fibers as a by-product. The examples of primary plants are Jute, Hemp, Kenaf and Sisal. Examples of secondary plants are pineapple and coir. The table above demonstrates the main commercially used fibers in composites which are now manufactured all over the world

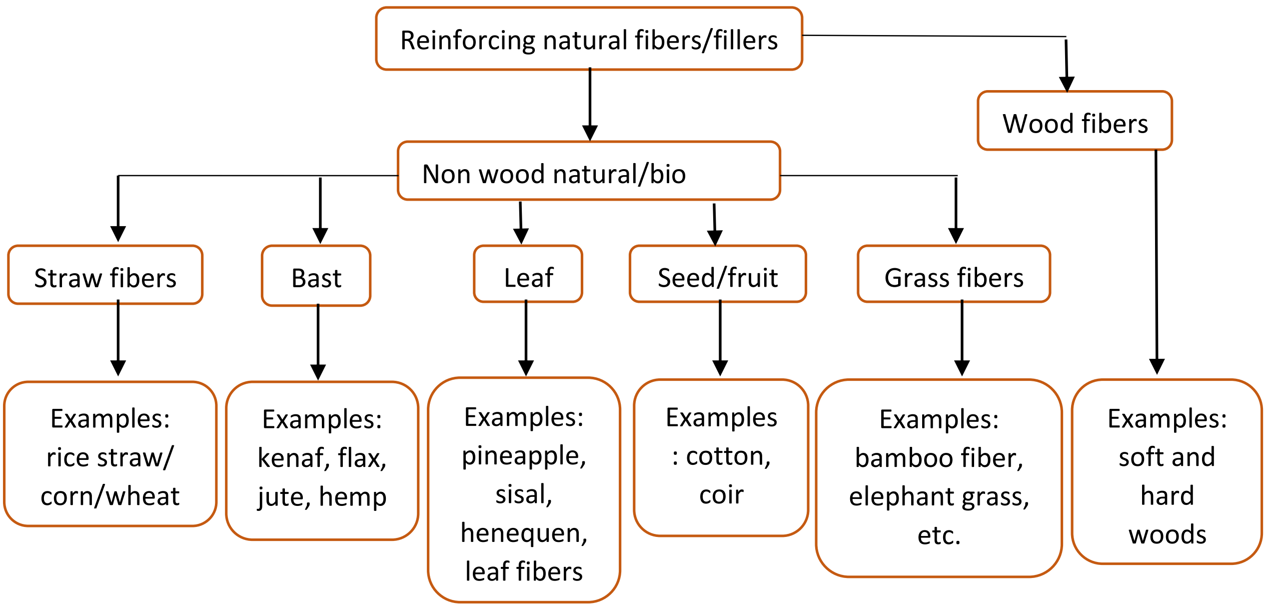


Figure 2.1: Classification of natural fiber. (Bharath & Basavarajappa, 2016)

## 2.2 Process of Biocomposite

Since there are many benefits to natural fibers including low cost, lightweight and biodiversity, researchers are beginning to make more efforts in this field in using natural fibers for polymers. (Jawaid, Alothman, & Salit, 2017). Bio composites are structures composed of biomaterial compounds with a filling component scattered through the matrix material or structures of separate sections of material (L.K. Cardon et al., 2017). The choice of the manufacturing method is affected by the products used and their required characteristics. The key considerations are material temperature processing.  The required overall porosity and the required size of fiber structures, geometric modifications or periodicity are the required control rates for the distribution of different materials, proportional as well as geometrical. (Ludwig K. Cardon et al ., 2009).

### 2.2.1 Conventional Composite Processing Techniques

The choice of the production methods depends directly on the materials and the desired properties of the final product. The subtopic below discusses the principle and implementation of conventional extrusion and injection, filament winding, compression, infusion, autoclaving and additive manufacturing (AM) techniques.

#### 2.2.1.1 Extrusion and Injection for Thermoplastic Materials

A "conventional" technique can be applied to bio composite compounds with a thermoplastic material as a matrix that also applies to everyday plastic products. This technique includes short fibers and/or particles in the composite reinforcement phase Extrusion and injection moldings both are based on the polymer melt's plasticity. The pure or compound polymer granules are dropped from a hopper system into a heated barrel, where the plasticized material is fed by a well-designed screw. This feed is continuous with extrusion and the material is extruded into a filament, foil or profile by a die (L.K. Cardon et al., 2017). These conventional techniques can often be used for the smaller scale production of thermoplastic bio composites part. The technical variant of biodegradable poly (lactic acid), which are processed by extrusion and injection, are industrially used as material for packaging and disposable parts. (Ludwig K. Cardon et al., 2009)