MECHANICAL PROPERTIES OF A COCONUT FIBER/ RECYCLED POLYPROPYLENE COMPOSITE SANDWICH STRUCTURE FABRICATED USING FDM PRINTING

NASRIN QISTINA BINTI NAZARUDDIN
B092010352

BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PRODUCT DESIGN) WITH HONOURS

2024

Faculty of Industrial and Manufacturing Technology and Engineering

MECHANICAL PROPERTIES OF A COCONUT FIBER/ RECYCLED POLYPROPYLENE COMPOSITE SANDWICH STRUCTURE FABRICATED USING FDM PRINTING

Nasrin Qistina Binti Nazaruddin

Bachelor of Manufacturing Engineering Technology (Product Design) with Honours

2024

MECHANICAL PROPERTIES OF A COCONUT FIBER/ RECYCLED POLYPROPYLENE COMPOSITE SANDWICH STRUCTURE FABRICATED USING FDM PRINTING

NASRIN QISTINA BINTI NAZARUDDIN

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

Faculty of Industrial and Manufacturing Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Mechanical Properties of Coconut Fiber/Recycled Polypropylene Composite Sandwich Structure Fabricated Using FDM Printing**

SESI PENGAJIAN: **2023-2024 Semester 1**

Saya **Nasrin Qistina Binti Nazaruddin**

mengaku membenarkan tesis ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Tesis 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 tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐	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	

Disahkan oleh:

Alamat Tetap:

No 18 Jln Cenderawasih 3, Taman Desa Keliang,
44100 Kerling, Selangor

Cop Rasmi:

TS. DR. YUSLIZA BINTI YUSUF
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan Pembuatan
Fakulti Teknologi dan Kejuruteraan
Industri dan Pembuatan
Universiti Teknikal Malaysia Melaka

Tarikh: 29/1/2024

Tarikh: 5/2/2024

** Jika tesis 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 Choose an item. entitled "Mechanical Properties Of A Coconut Fiber/ Recycled Polypropylene Composite Sandwich Structure Fabricated Using FDM Printing" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Nasrin Qistina Binti Nazaruddin

Date : 29/1/2024

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 (Product Design) with Honours.

Signature : ....

Supervisor Name : Ts Dr Yusliza Binti Yusuf

Date : 5/2/2024

DEDICATION

I dedicate this to my beloved immediate family, beloved friends and esteemed supervisors

ABSTRACT

Natural fibers has been on the rise due to the fact from the increasing enviromental impact that was due to synthetic fiberwhich brings more harm than good for the environment. Meanwhile Recycled Polypropylene is a recycled thermoplastic that has alot of application such as FDM printing as a filament and it also has many advantages including great mechanical properties, ecologically and financially. Thus combining thesee two into a composite for a filament as it would make a great composite as both provide great mechanical properties together according to a few studies and it is enviromentally friendlly too . Especially since the rising enviromental impact from the constant use of plastic especially in the FDM printing industry. Not too mention most thermoplastic that is used in FDM printing tends to be brittle. Thus, fabricating a enviromentally friendly option for FDM printing using the coconut fiber/Recycled Polypropylene is a must. Althought the mechanical properties of the coconut fiber/Recycled Polypropylene must be studied as most studies focuses on injection moulding rather than FDM printing. To produce said coconut fiber/Recycled Polypropylene composite, one must first prepare the raw material and mix it together with a hotpress machine before inserting it into a single screw extruder for fabricating a filament for FDM printing in which will be printing a Honeycomb Sandwich Structure (HCSS) in which it will be used as testing specimen for multitude of test such as tensile and flexural. However, the results obtained are contrasting towards the result obtained as the result obtain in actual is that the 1% wt is higher than the others whilst the literature states that 5% wt supposed to be highest in all of the mechanical test. This could happen due to not properly treating the fibers and the HCSS FDM printing could be a problem occuring through it. In conclusion, this study made a contribution but nevertheless needs to be further studied.

ABSTRAK

Pengunnan serat semula jadi didalam industri meningkat dek kerana daripada kesan peningkatan masalah alam sekitar yang disebabkan oleh serat sintetik yang membawa lebih banyak keburukkan daripada kebaikan untuk alam sekitar. Manakala, polipropilena kitar semula adalah termoplastik kitar semula yang mempunyai banyak aplikasi seperti percetakan FDM sebagai filamen dan ia juga mempunyai banyak kelebihan seperti mempunhyai sifat mekanikal yang tinggi, dari segi ekologi dan kewangan. Oleh itu, dengan menggabungkan kedua-dua bahan untuk dijadikan sebagai komposit untuk filamen adalah wajar dek kerana kedua-duanya mempunyai sifat mekanikal yang berdasarkan beberapa kajian yang telah dibuat. Terutama sekali sejak peningkatan kesan peningkatan masalah alam sekitar dari penggunaan plastik yang berterusan terutama sekali di dalam industri percetakan FDM. Tidak dinafikan juga bahawa kebanyakan termoplastik yang digunakan didalam percetakan FDM cenderung untuk menjadi rapuh. Oleh itu, membuat pemilihan untuk menjadi lebih mesra alam sekitar untuk percetakan FDM menggunakan serat kelapa / polipropilena kitar semula adalah digalakkan. Walau bagaimanapun sifat mekanikal serat kelapa / polipropilena kitar semula perlu dikaji kerana kebanyakan kajian memfokuskan pada 'injection moulding' dan bukannya percetakan FDM. Oleh sebab itu, untuk menghasilkan serat kelapa / komposit polipropilena kitar semula, bahan mentah perlu disediakan dan mencampurkannya dengan mesin 'hotpress' sebelum memasukkannya ke dalam 'single screw extruder' untuk membuat filamen untuk percetakan FDM yang akan dicetak sebagai 'Honeycomb Sandwich Structure (HCSS)' , di mana ia akan digunakan sebagai spesimen ujian untuk banyak ujian egangan dan lentur. Walau bagaimanapun, keputusan yang diperolehi adalah berbeza dengan keputusan yang dikaji. Hal imi kerana keputusan yang diperolehi sebenarnya ialah 1% berat lebih tinggi daripada yang lain manakala literatur menyatakan bahawa 5% berat sepatutnya tertinggi dalam semua ujian mekanikal. Ini boleh berlaku kerana tidak merawat gentian dengan betul dan pencetakan HCSS FDM boleh menjadi masalah yang berlaku melaluinya. Kesimpulannya, kajian ini memberi sumbangan tetapi masih perlu dikaji lebih lanjut

ACKNOWLEDGEMENTS

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

I would like to first and foremost to praise our almighty God, Allah SWT, for everything I received and achieve in my life. I would also like to give my thanks to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the chance to study herer .

Secondly I would like to give my appreciation of thanks to my main supervisor, TS. Dr. Yusliza Binti Yusuf, from the Universiti Teknikal Malaysia Melaka (UTeM) for all her support, advice and inspiration. Her constant patience for guiding and providing for insights will forever be remembered. Also, to my co-supervisor, Dr Nuzaimah Bte Mustafa Universiti Teknikal Malaysia Melaka (UTeM) who also guided me and provide me with feedback

Last but not least, from the bottom of my heart I would like to extend my love and thanks to my parents, Nazaruddin Bin Muhamad and Azura Binti Ahmad, for their constant love and encouragements. My love also extend to all of my friends, for their patience and resourcefulness. Finally, thank you to all the individual(s) who had provided me the assistance, support and inspiration to embark on my study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

PP	-	Polypropylene
R-PP	-	Recycled Polypropylene
HCSS	-	Honeycomb Sandwich Structure
ABS	-	Acrylonitrile Butadiene Styrene
TPU	-	Thermoplastic polyurethane
FDM	-	Fused Deposit Modeling
NaOH	-	Sodium Hydroxide
NFRPCs	-	Natural fiber–reinforced polymer composites
PLA	-	Polylactic Acid

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
Appendix A	Gantt Chart PSM I	74
Appendix B	Gantt Chart PSM II	75

CHAPTER 1

INTRODUCTION

1.1 Background

The rise of natural fibers has been contributed from the enviromental impact that was caused by synthetic fibers which brings more harm than good for the environment. New environmentally acceptable alternatives were considered as a result of growing environmental concerns amd new environmental regulations. Natural fibers cost less, is renewable, is biodegradable and eco-friendly. In supporting to these, it is a potential candidate in number of engineering applications replacing the synthetic fibers (Kumar and Shamprasad, Coconut coir fiber reinforced polypropylene composites: Investigation on fracture toughness and mechanical properties 2021). A few example natural fibers examples are kenaf, wood, coconut and many more. Thus based on this, coconut fiber is chosen to be used as it's natural fiber as it has excellence mechanical properties.

Meanwhile, Recycled Polypropylene (PP) is one of the most extensively used thermoplastics both in developed and developing countries as it provides advantages in regard to economy, ecological and technical requirements (M. Haque, Nazrul Islam, Saiful Islam 2010). Thus Recycled Polypropylene makes it suitable as a matrix. As being able to penetrate between fibers and form a solid interfacial bond makes it a viable candidate for use as a matrix material.

Recycled Polypropylene is also known as a thermoplastic that is widely used as a feedstock material in FDM printing. FDM printing is an additive manufacturing (AM) technique known as fused deposition modelling (FDM) uses long, continuous solid flament as a feedstock. This technique is widely used, especially in engineering applications for creating prototypes, conceptual models, and engineering parts. Recently however, FDM printing technique is used to print sandwich structure (Ahmad, et al. 2023). Sandwich structure is a structure is constructed by joining two lightweight but thick cores to two rigid but thin shells. The sandwich composite has a high bending stiffness and a generally low density thanks to the increased thickness of the core material, which is often low strength.

One of the most common used sandwich structure in FDM printing is Honeycomb Sandwich Structure (HCSS).

1.2 Problem Statement

Plastic has grown in popularity since its invention in the beginning of the 20th century and is now employed in a wide range of applications. As such even in Fused Deposit Modeling (FDM). However, a problem arises when the material used such as Acrylonitrile Butadiene Styrene (ABS) and Polypropylene can't be properly recycled as most municipal curbside recycling programs don't recycle these materials. As both are classed as Type 7, or "Other," according to the ASTM International Resin Identifier Codes, which are not normally processed by municipal programs (Maidin 2017). This poses a risk to the enviroment and can cause an enviromental impact as the plastic cannot be properly recycled. As such to combat this, a more enviromental friendly substitute is introduced such as a filament made from Coconut fiber/Recycled Polypropylene .

In addition of the current market of filaments are not as enviromentally friendly in Fused Deposit Modeling (FDM) , the materials properties are not as good as natural fiber composites in terms of varieties of properties such as mechanical and physical, properties. This could indicate that the filaments are brittle in terms of its fracture toughness and flexural strength in terms of mechanical properties (S. Kumar, M. S. Shamprasad, et al. 2020). This could indicates that the lower the value, the less impacting forces the material can withstand to others unlike composites made out of natural fibers and thermoplastics. (Giohar, Hussain and Ali 2021). To overcome this problem, natural fiber with reinforced thermoplastic as matrix such as Coconut fiber/Recycled Polypropylene is made to ensure the mechanical properties of the filament that will be used to FDM print the sandwich structure will be ductile enough.

1.3 Research Objective

The main aim of this research is to study the mechanical properties of Coconut fiber and Polypropylene composite sandwich structure fabricated using FDM printing. Specifically, the objectives are as follows:

a) To fabricate a sandwich structure based on environmentally friendly composite such as Coconut fiber and Recycled Polypropylene using FDM printing.

b) To evaluate the mechanical properties of Coconut fiber and Polypropylene composite honeycomb structure performance.

1.4 Scope of Research

The main scope for this research is to investigate mechanical properties of a Coconut fiber/Polypropylene composite in regards to sandwich structure fabricated using FDM printing. This research also includes:

a) Each of the composites are divided into three ratio each which is 1%, 3% and 5% for both treated and untreated
b) The treated coconut fiber consist of 6% NaOh
c) Printing the sandwich structure as a Honeycomb Sandwich Structure (HCSS) using the FDM printing technique.
d) Evaluating the mechanical properties by using flexural test, impact test and tensile test on the Honeycomb Sandwich Structure (HCSS) based on the standards of each test.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In today's modern society, environmental impact is taken very seriously especially in the recent climate changes that is happening. Modern environmentalist concerns incorporate climate changes and man-made tragedies due to reckless industrial practices. Due to that, various ways are introduced to reduce the environmental impact such as in this research regarding on fabricating a filament made of natural fiber such as coconut fiber with polypropylene as matrix to produce filaments for 3D printing in regards to finding the mechanical properties.

2.2 Natural fiber in Composite

Natural fibers are those made from the bodies of plants or animals or by geological processes. They can be utilized as a part of composite materials, where the qualities are affected by the orientation of the fibers. To manufacture paper or felt, natural fibers can also be matted into sheets. Natural fibers can also be made into Natural fiber–reinforced polymer composites (NFRPCs). It's gaining favor over synthetic fiber owing to their lower cost and environmental friendly characteristics, as they exist abundantly and are renewable (Thyavihalli Girijappa, et al. 2019). Examples of natural fibers are divided into two categories which are The primary plants are those grown for their fiber contents while secondary plants are those where the fibers come as a by-product from some other preliminary utilization. Jute, kenaf, hemp, sisal, and cotton are examples of primary plants while pineapple, cereal, stalks, agave, oil palm, and coir are examples of secondary plants. Natural fibers derived from plants consist of cellulose, hemicellulose, lignin, pectin, and other waxy substances, In various applications, natural fibers extracted from plants are used as reinforcements in both thermoplastic and thermoset composites as the properties of natural fibers known to increase mechanical properties of the thermoplastic. The table 2.1 below shows each type natural fiber's mechanical properties in composite such as density, tensile strength, Young's modulus and elogation at break.

Table 2.1 Type of natural fibers mechanical properties in composite.

Fiber	Density (g/cm^3)	Tensile Strength (MPa)	Young Modulus (GPa)	Elongation at break %
Jute	1.23	325–770	37.5–55	2.5
Kenaf	1.20	745–930	41	1.6
Hemp	1.35	530–1,110	45	3
Flax	1.38	700–1,000	60–70	2.3
Coir	1.20	140.5–175	6	27.5
Banana	1.35	721.5–910	29	2
Sisal	1.20	460–855	15.5	8

2.2.1 Types of Natural fiber

Fibrous plant material created as a result of photosynthesis is referred to as natural fiber. Another common name is "lignocellulosic fibers," which means "containing lignin and cellulose," despite the fact that some of the fibers mentioned (cotton) have very little or no lignin. Natural fibers are made from plants, and while the fibers themselves are renewable and sustainable, it is the living plants that are. Plants that produce natural fibers fall into one of two categories: primary or secondary, depending on how they are used. Plants produced for their fiber content are considered primary, whilst those whose fibers are a byproduct of another major use are considered secondary. Examples of primary plants include cotton, jute, hemp, kenaf, sisal, and pineapple. Meanwhile examples of secondary plants include agave, oil palm, coir, and cereal stalks. Natural fibers are also often categorised by the type of plant they come from. Six fundamental categories of natural fibers can be identified using this system bast fibers such as jute, flax, hemp, ramie and kenaf, leaf fibers such as banana, sisal, agave and pineapple, seed fibers such as coir, cotton and kapok, core fibers such as kenaf, hemp and jute, grass and reed such as wheat, corn and rice and finally all other types are called as such as wood and roots (Rowell 2008). The table 2.2 below shows the type of byproduct of the natural fiber from each of their individual trees.

Table 2.2 The table below shows the type of byproduct of the natural fibers.

Bast	Leaf	Seed					Core	Grass/reeds	Others
		Fibers	Pod	Husk	Fruits	Hulls			
Hemp	Pineapple	Cotton					Kenaf	Wheat	Wood
Ramie	Sisal		Loofa				Jute	Oat	Roots
Flax	Banana		Milk Weed				Hemp	Bamboo	
Kenaf	Palm			Coir			Flax	Barley	
Jute	Agave				Oil Palm				
						Rice			
						Oat			

2.2.2 Coconut fiber in Composite

Coconut fiber, obtained from unripe coconut, which is commonly found in abundance in South and South East Asian countries is a natural fiber extracted from the husk of coconut. It's name from the word Kayar which originates from Malayalam which means rope. Coconut fiber is known to have higher lignin that other types of natural fibers such as flax, hemp and wool (Mishra and Basu 2020). Unbeknown to most, lignin is important as its capacity to absorb water up to seven times its weight makes it perfect. The process of obtaining the coconut fiber is that the coconut is steeped in hot seawater, and subsequently, the fibers are removed from the shell by combing and crushing, the same process as jute fiber. The individual fiber cells are narrow and hollow with thick walls made of cellulose, and each cell is about 1 mm long and 10–20 μm in diameter. Meanwhile, the raw coconut fibers show length varying from 15 to 35 cm and diameter from 50 to 300 μm. Though, each countries or region that have coconuts, have different chemical composition. This is probably due to the different types of coconut species that each country has. Thus making each chemical composition differ slightly.

2.2.3 Properties of Coconut fiber

Coconut fiber main component structure is made entirely of cellulose, hemi-cellulose, and lignin. They also contain various minor components, such as pectin, inorganic salts, nitrogenous substances, coloring agents, waxes, and other compounds.The lignin content in coconut fibers is very high due to natural fibers have a hydrophilic nature. Polysaccharides like cellulose and hemicellulose, along with macromolecular polyphenolic compounds such as lignin, play significant roles in composites. Achieving strength and ductility in a composite material involves considering the bonding between the fiber surface and the matrix, the fiber construction method, and ensuring that the reinforcing component has a higher elastic modulus than the matrix. The properties of the composite heavily rely on the compatibility between natural fibers and the matrix material. (Arsyad, et al. 2015) Though to have a better and stronger bonding strength, it is recommended to use a treatment to treat the surface of the Coconut fiber so that the bonding strength increases. The Table 2.3 below shows the comparison of chemical composition of coconut fiber and jute fiber.

Table 2.3 The Chemical composition (in percent of bone dry weight)and fine structure parameters of coconut fiber and jute.

Composition	Coconut Fiber	Jute
Cellulose	35-43	58-59
Lignin	40-45	12-14
Hemicellulose	0.15-24	14-25
Water Soluble	5.25	-
Pectin	3.3-4.0	0.2-0.5

2.2.4 Natural fiber Treatment Process

A growing number of polymer composites are using natural fibers as reinforcement because of their potential mechanical qualities, production advantages, and environmental advantages. However, the fiber’s hydrophilic nature reduces their compatibility with the matrix. Poor mechanical characteristics of the composites are caused by this incompatibility. Due to this natural fibers are needed to undergo chemical treatment to strengthen the bond between the natural fiber and matrix. As natural fibers do, however, have some drawbacks and are not a problem-free substitute. Their structural makeup (cellulose, hemicelluloses, lignin, pectin, and waxy components) permits moisture absorption from the environment, which results in poor bonding with the matrix materials, thus needing to be chemically treated. There are multiple way to chemically treat the natural fibers such as alkaline treatment or mercerization, silane treatment, Acetylation treatment or also known as esterification, Maleated coupling agents, sodium hlorite treatment and many more. No matter what kind of treatment and method that are used, all of the treatment have one thing in common which is to treat the natural fibers for better bonding with the matrix. (Kabir, et al. 2012).

Commonly used treatment in treating natural fibers are mercerization and silane treatment. Mercerization process depolymerizes cellulose, exposes the short length crystallites, and eliminates some of the lignin, wax, and oils covering the exterior surface of the fiber cell wall. Thus, making alkaline treatment has a long-lasting impact on natural fibers mechanical behaviour, particularly on strength and stiffness. (Li, Tabil and Panigrahi 2007). Meanwhile for silane treatment, in which modifies the surfaces of fibers by acting as a coupling agent. Through the creation of a siloxane bridge, the silane's chemical structure connects the matrix and fiber surface. As the fiber is being treated, it passes through numerous steps of hydrolysis, condensation, and bond formation. Thus showing that silane-treated fiber composites offer better flexural and strength qualities (Kabir, et al. 2012). The Figure 2.1 below shows the typical structure of difference between treated and untreated natural fiber using alkaline treatment

$$\text{Fibre-cell-OH} + \text{NaOH} \longrightarrow \text{Fibre cell-O}^{-}\text{Na}^{+} + H_2O + \text{impurities} \quad (1)$$

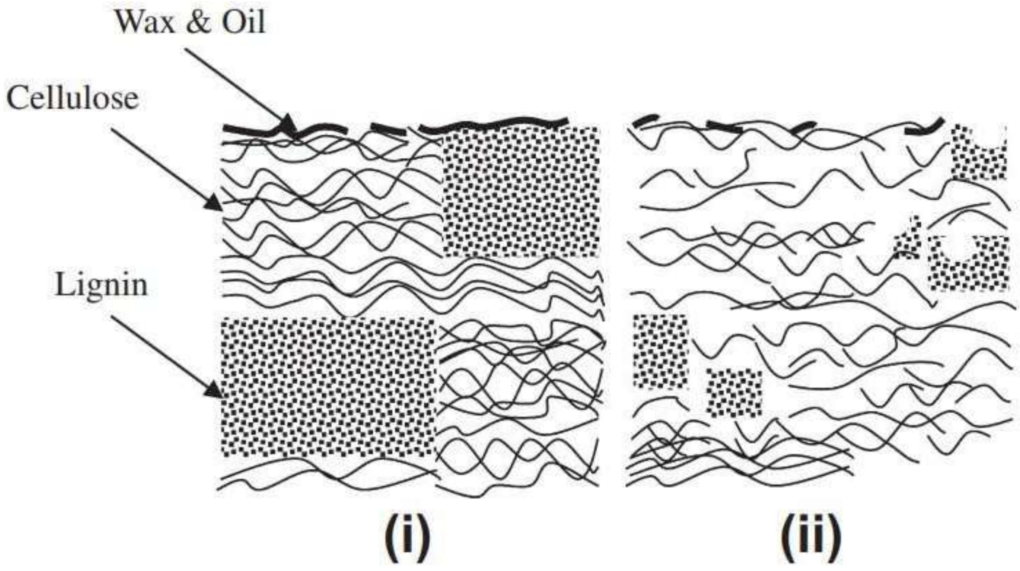


Figure 2.1 The typical structure of untreated (i) and treated (ii) natural fiber with alkaline treatment

2.3 Polypropylene (PP)

Polypropylene (PP) is a thermoplastic polymer that is partially crystalline and non-polar. It is used in a wide variety of applications and is the second-most widely produced commodity plastic after polyethylene. It is made by polymerizing more propylene monomers, thus polypropylene is produced. Chemically speaking, propylene is 2-methyl ethylene with an extra CH3 group compared to ethylene. The CH3 group is crucial because it can be organised in many spatial conformations in macromolecules and produce products with various characteristics as a result. The resulting polypropylene materials can be broadly categorised as isotactic, syndiotactic, and atactic polypropylene. In the first instance, the polymer's main chain's CH3 groups are positioned on the same side. Syndiotactic means that the CH3 groups are symmetrically positioned on the two sides of the main chain. Astatic refers to a situation where the CH3 groups are spatially dispersed at random with respect to the main chain (Gopanna, et al. 2019) .

Polyproplene matrix is a known thermoplastic polymer with excellent properties, including high gas and water permeability resistance, mechanical properties, and in addition to having a very high flex rate, it also boasts low cost, excellent wear resistance, and high temperature resistance (Gopanna, et al. 2019). The Figure 2.2 shows the Polypropylene (PP) matrix structurecand Table 2.4 below showcase the Polypropylene (PP) mechanical prorperties.

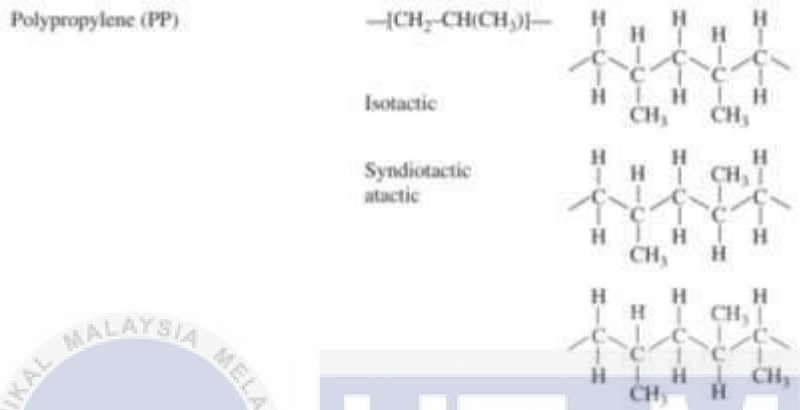


Figure 2.2 The structure of Polypropylene (PP) Matrix

Table 2.4 The mechanical properties of Polypropylene (PP) Matrix,

Property	Units	Value
Density	g/cm³	0.9
Tensile Strength, 73 ºF	psi	4500
Flexural modulus of elasticity, 73 ºF	psi	17 000-100 000

2.3.1 Recycled Polypropylene (R-PP)

Even for Recycled Polypropylene, the properties won't change from normal polyproplyne. Recycled polyprolyne happens due to demand of polypropylene that kept increasing over the years. Thus to curb the enviromental problems that may occur in the future and to supply ongoing demand for the use of polypropylene, Recycled Polypropylene is created (Brachet, , et al. 2008). However, recycling causes PP embrittlement, which is confirmed by the reduction in impact strength (Barbosa 2017).

2.3.2 Recycled Polypropylene in Natural fiber

The growing acceptance of additive manufacturing technologies has been accompanied by environmental consciousness has prompted a push to create novel, sustainable composites. In reinforced polymer composites in particular, natural fibers arincreasingly favoured as an alternative probably due to the fact that the processing required to produce synthetic fibers requires a lot of energy. Natural fibers not only have exceptional tensile qualities but are also biodegradable and renewable.. It is known that natural fibers reinfoced with Recycled Polypropylene have good mechanical properties. It is found that by using natural fibers it is known for boosting strength and stiffness, supporting their use in FDM, even though characteristics were found to be lower for printed specimens than for filament, supporting the need to improve print-quality (Milosevic, Stoof and Pickering 2017). Figure 2.3 below shows the comparison of mechanical properties of natural fiber reinforced polypropylene.

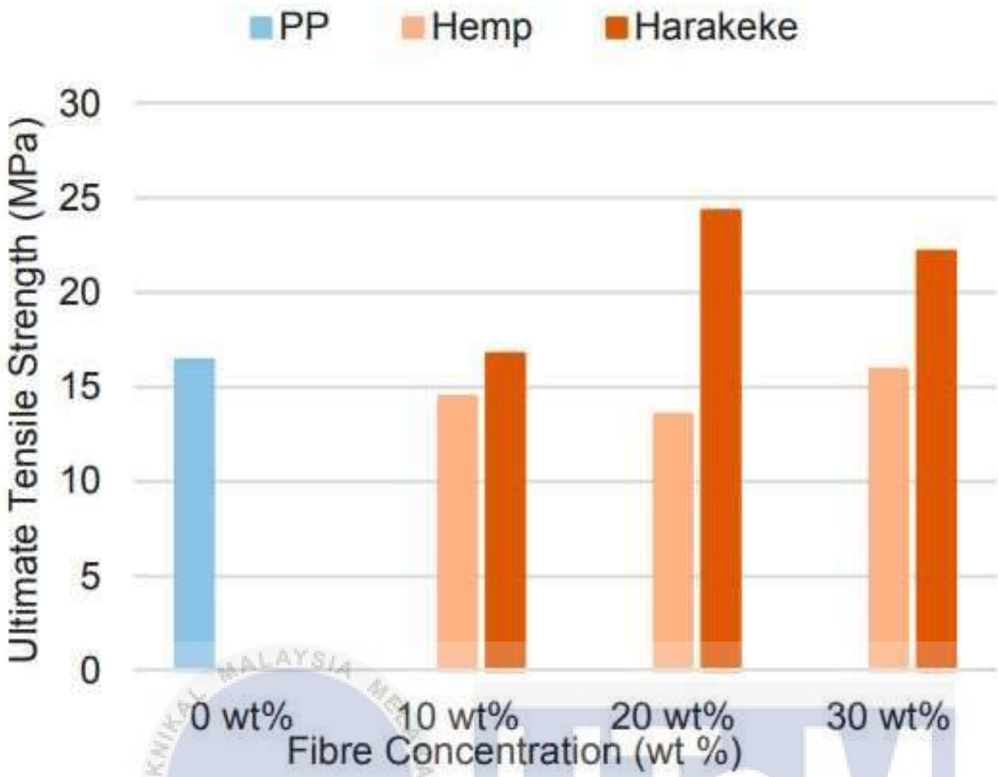


Figure 2.3 Tensile Strength of Natural fibers/ Polypropylene (PP)

2.4 Honeycomb Sandwich Structure (HCSS)

Natural or artificial structures with a honeycomb-like form allow for the minimization of the quantity of material utilized to achieve minimal weight and minimal material cost. Although the geometry of honeycomb structures can vary greatly, they all include an array of hollow cells produced between slender vertical walls. The form of the cells is frequently hexagonal and columnar. Due to their characteristics, such as a high strength to weight ratio, stiffness, and impact strength, honeycomb sandwich structures (HCSS) have many uses in the aerospace, automotive, satellite industries and many more. The flexibility, ease of use, speed of production, affordable cost, and design freedom of the Fused Deposition Modelling (FDM) method make it capable of enhancing the capabilities of HCSS (Giohar, Hussain and Ali 2021). The Figure 2.4 below shows the typical structure of Honeycomb Sandwich Structure (HCSS)

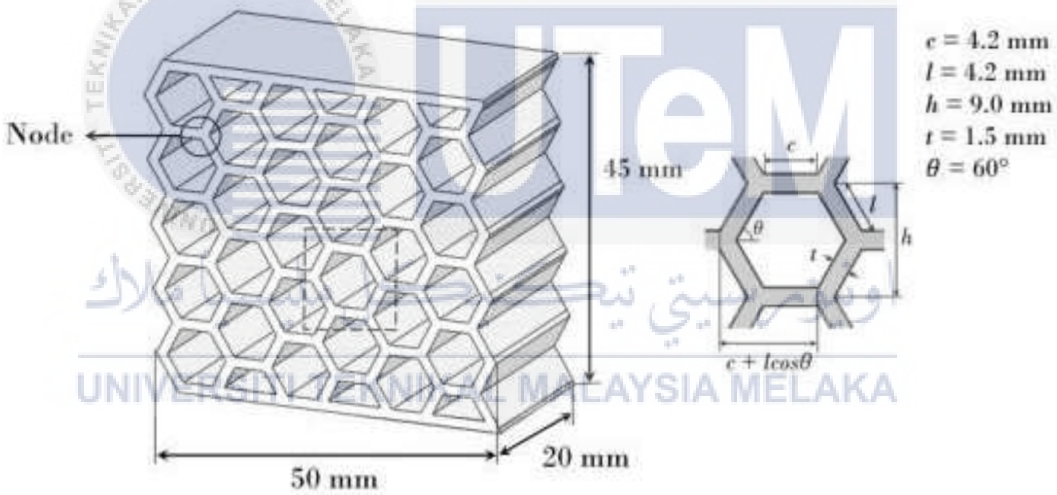


Figure 2.4 The Honeycomb Structure Sandwich (HCSS)

2.4.1 Composite Honeycomb Sandwich Structure (HCSS) in FDM Printing

In most cases, Honeycomh Sandwich Structure uses FDM printing as FDM widely used additive manufacturing process for the fabrication of simple and complex structures. Honeycomb Sandwich Structure (HCSS) comes in all types of material from metal such as Aluminum, Aluminum Alloy and Stainless Steel. There are also Honeycomb Sandwich

Structure (HCSS) that uses thermoplastics such as Polylactic Acid (PLA) and even Polypropylene (PP). (F, et al. 2022). However, the rise of natural fiber composite has been taken into factor in terms of recyclability, renewability, biodegradability. Such natural fiber composite that has been used for Honeycomb Sandwich Structure (HCSS) in FDM Printing are Hemp/Polylactic Acid (PLA) (Antony, Cherouat and Montay 2020), Wood/Polylactic Acid (PLA) (Ayrilmis, Nagarajan and Kitek 2020). Both of these natural fiber composites shows sufficient properties in terms of analysis of their mechanical properties such as impact test, flexural test and bending test. The analysis provided sufcient mechanical properties of the honeycomb structure which can assist in designing a better fnal part. (Antony, Cherouat and Montay 2020).

2.5 Summary

To summarize it all, there aren’t a lot of research that are shown to have done a natural fiber composite in a Honeycomb Sandwich Structure (HCSS) using FDM process, only a few such as Hemp/Polylactic Acid (PLA), Wood/Polylactic Acid (PLA) and a few more. However, when done the research separately, it can be concluded that Honeycomb Sandwich Structure (HCSS) can assist on making the mechanical properties of the part better and natural reinforced filament tends to perform even better when it comes to mechanical properties. So in short, in theory Coconut Fiber/ Recycled Polypropylene Honeycomb Sandwich Structure (HCSS) using FDM process will fabricate good mechanical properties.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the methodology describes the process and flowchart on continuing on the project to achieve the objectives and being able to focus fully on the scope provided. The methodology flowchart below shows the flowchart of the whole process of making the Coconut fiber/ Recycled Polypropylene from scratch to the end until the sandwich is formed from the powdered materials to filament produced from the byproduct of the composition and finally to a sandwich structure that is needed to be tested for it's mechanical properties. Thus which later will be tested using various testing method from mechanical testing such as flexural and tensile test and also physical tests such as water absorption test. The table 3.1 below shows the process flow of the study.

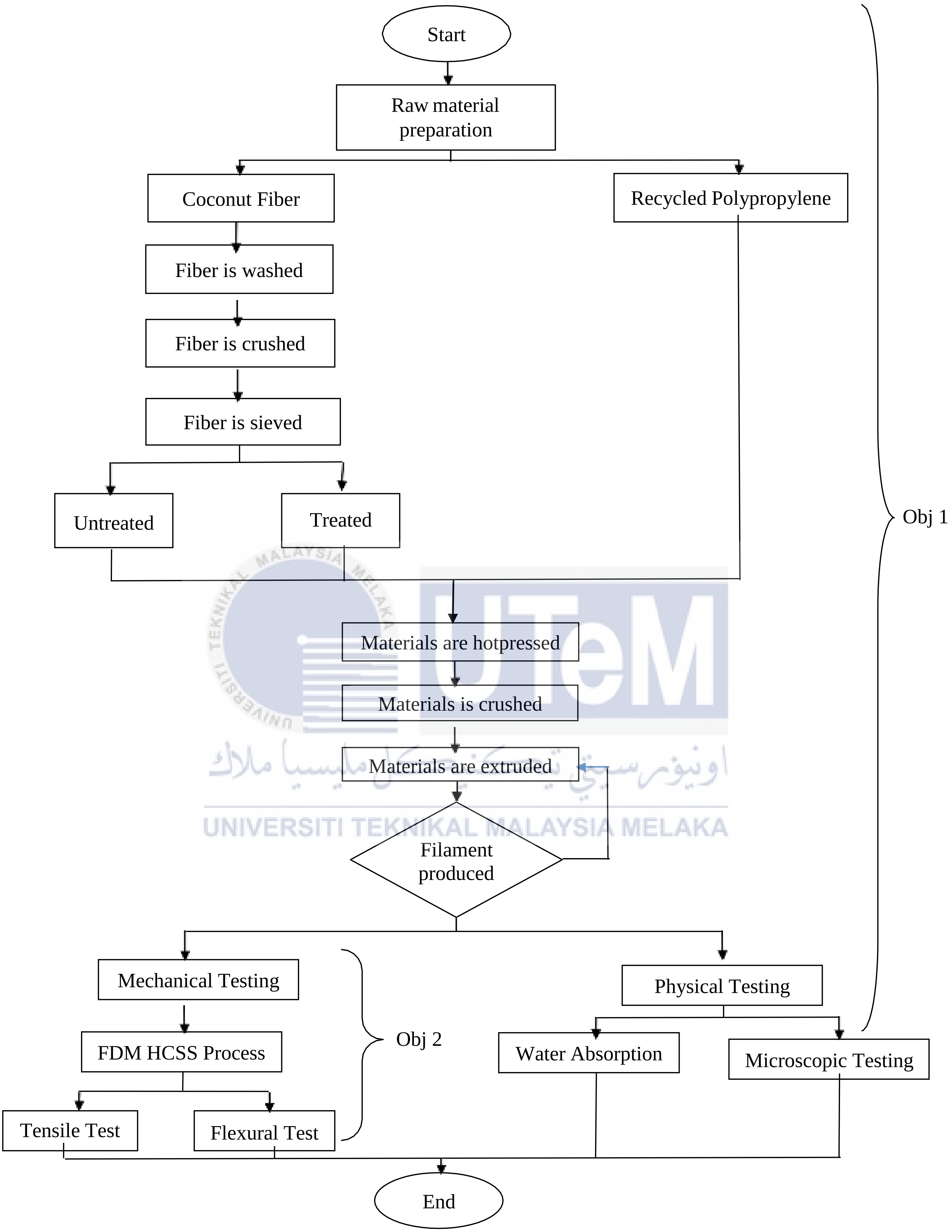


Figure 3.1 Process flow of the study

3.2 Raw Material Preparation

3.2.1 Coconut fiber Preparation

The raw coconut fiber is obtained from the local online shopping center Shopee and the coconut fiber is sourced in Terengganu, Malaysia. The coconut fiber comes in the shapes of strands. The Figure 3.2 below shows the coconut fiber bought from Shopee that is sourced from Terengganu, Malaysia.

Figure 3.2 Coconut fibers bought from Shopee that is sourced from Terengganu, Malaysia

Due to its raw nature, the coconut fiber is first thoroughly washed using cold water to extract the dirt from the coconut fiber. It is doused inside a container of cold water for 20 minutes to ensure the dirt and other foreign matter is separated and gone from the coconut fiber. Once it is washed and doused, the coconut fiber was left in the sunlight until it fully dries. Figure 3.3 below shows the coconut strands before it was doused in cold water.

Figure 3.3 Coconut fiber strands before being doused in cold water.

The next step is to grind the said raw coconut fiber using a grinder. Although, the coconut fiber strand is cut into smaller piece which is <10mm to ensure that the coconut fiber will be able to grind until it is fine enough (S. Kumar, M. S. Shamprasad, et al. 2020). The Figure 3.4 (a) shows the <10mm coconut fiber strand and (b) the grinder that is used for grinding the fiber into powder.

(a) (b)

Figure 3.4 (a) The <10mm coconut fiber strand and (b) the grinder that is used for grinding the fiber into powder.

The powdered coconut fiber must be grinded until it is at least suitable to be sieved which is required it to be <125 µm. The seived coconut fiber is then divided into two sections for which it will be categorized as treated and untreated coconut fiber. The Figure 3.5 shows the grinded coconut fiber.

Figure 3.5 The grinded and sieved coconut fiber.

The treated coconut fiber will be doused in mixture of Sodium Hydroxide (NaOH) in which six percent of Sodium Hydroxide (NaOH) out of 1000g solution were solvent in a twelve litres of distilled water for two hours at room temperature and dousing it once more in distilled water and cold water to remove excess Sodium Hydroxide (NaOH) (Mohd Latip 2017). Figure 3.6 (a) shows the sieved coconut fiber with Sodium Hydroxide (NaOH) and Figure 3.6 (b) shows the stirred coconut fiber with Sodium Hydroxide (NaOH).

(a) (b)

Figure 3.6 (a) The sieved coconut fiber with Sodium Hydroxide (NaOH) and (b) the stirred coconut fiber with Sodium Hydroxide (NaOH)

The mixture is then put inside a tray that is alligned with aluminium foil. It is then inserten and dried in the oven for 24 hours with the temperature of 80 ºc. The Figure 3.7 (a) shows the treated coconut fiber inside the tray whilst (b) shows the treated coconut fiber being put inside the oven for 24 hours.

(a) (b)

Figure 3.7 (a) The treated coconut fiber inside the tray and (b) the treated coconut fiber being put inside the oven for 24 hours.

After the 24 hours is up, the trays containing the coconut fiber is taken out, the treated coconut fiber is once again grinded into powder and the powdered coconut fiber is then put inside a sample bag for the next steps. The Figure 3.8 shows the treated coconut powder inside a sample bag. Meanwhile Figure 3.9 shows the flow of the whole process.

Figure 3.8 The treated coconut fiber inside a sample bag

Figure 3.9: The flow of coconut fiber preparation process

3.2.2 Recycled Polypropylene Preparation

For preparations regarding recycled Polypropylene, it doesn't need any preparation as it comes in a bag and can be mixed using the method of hot press. Figure 3.10 below shows the Recycled Polypropylene obtained from the bag.

Figure 3.10 Recycled Polypropylene

3.3 Filament Fabrication

3.3.1 Mixing Process using Hot Press Machine

Before mixing using a hot press machine, the treated and untreated coconut fiber were divided into percentage by weight of 1 wt%, 3 wt% and 5 wt% based on the ratio between coconut fiber and Recycled Polypropylene in each division of treated and untreated composite. The amount needed for the composite to mix is in total 720g for each percentage. The Table 3.1 below shows the calculation of the composite as for each of the weight percentage that will equal the weight of each in accordance to the mould size (25 cm x 25 cm x 0.3 cm) using the mould density calculation. (Nasir , et al. 2022).

Table 3.1 Calculation of the composites

Weight percentage %	Coconut Fiber (g)	Recycled Polypropylene (g)
1%	$\frac{1}{100} x720 = 7.2g$	$720g - 7.2g = 712.8g$
3%	$\frac{3}{100} x720 = 21.6g$	$720g - 21.6g = 699g$
5%	$\frac{5}{100} x720 = 36g$	$720g - 36g = 684g$

$$\rho = \frac{m}{v}$$

$$V_{mould} = 24.8\ cm\ x\ 24.8\ cm\ x\ 0.3\ cm = 187.5\ cm^3$$

$$m_{mould} = V\ x\ 1.9157$$

$$m_{mould} = 187.5\ cm^3\ x\ 1.9157 = 359.19g\ per\ mould \quad (2)$$

The obtained weight is then put together using a hot press machine as shown in the figure below after selecting the mold size to use for each specimen that is needed. Although, the hot press machine has to be preheated for 5 minute with the temperature of 195 ºC. After choosing the perfect size of the mold which is 24 mm x 20 mm x 4 mm, both materials are added to the machine and needed to be waited for a total around 30 minutes for each specimen and each process (heating, hot pressing and cooling process). The Figure 3.11 below shows the hotpress machine that was used for this process.

Figure 3.11 The hotpress machine that was used for this process.

The process is repeated several times according to each percentage weight categories. After it is done, each specimen is categorized again into treated and untreated with each percentage weight (Mohd Latip 2017). The Figure 3.12 below shows the outcome of the 3% wt treated hotpressed composite of Coconut Fiber/Recycled Polypropylene.

Figure 3.12 The 3% wt treated hotpressed composite of Coconut Fiber/Recycled Polypropylene.

3.3.2 Crushing Process

After separating the treated and untreated with each different weight percentage after the composites cooled off. The hot-pressed composite will need to be cut into half using a saw table to fit into the crusher as the crushed is too small for the hotpressed composite. Figure 3.13 below shows the composite being cut into half for the crusher machine.

Figure 3.13 The hotpressed composite being cut into half for the crushed machine.

The composite will be inserted into the crusher one by one and in which it will become a pellet form that will feed into the single screw extruder machine. This action may need to be repeated a few times as it may not come out as small as it supposed to be to produce into pellets fit into going into an extruder. The Figure 3.14 (a) shows the cut up hotpressed composite being inserted into a crusher and (b) shows the crushed pellet of said composite.

(a) (b)

Figure 3.14 (a) The cut up hotpressed composite being inserted into a crusher (b) the crushed pellet of said composite.

Figure 3.15 Flow chart of crushing process

3.3.3 Extrusion Process

After the composites are crushed into a pellets, it is ready to be extruded into a filament roll. The parameter of settings of is first set to 2m/min^{-1} speed and 200 ºC for each barrel temperature that is in accordance to the materials of the composite which is Coconut Fiber/Recycled Polyproplene. The Figure 3.16 below shows the parameter being set in accordance to the materials.

Figure 3.16 Parameter of the extrusion machine in accordance to the materials.

The crushed pellet is then individually inserted for each percentage into the single extruder. The barrels will heat up as the pellets go through the screw. It is inserted into a hopper and the extrusion process starts and the end result is a roll of filament made of Coconut fiber/Recycled Polypropylene. The Figure 3.16 (a) shows the crushed pellet being inserted into a hopper and (b) below shows the filament slowly being made.

(a) (b)

Figure 3.17 (a) The crushed pellet being inserted into a hopper (b) filament slowly being made .

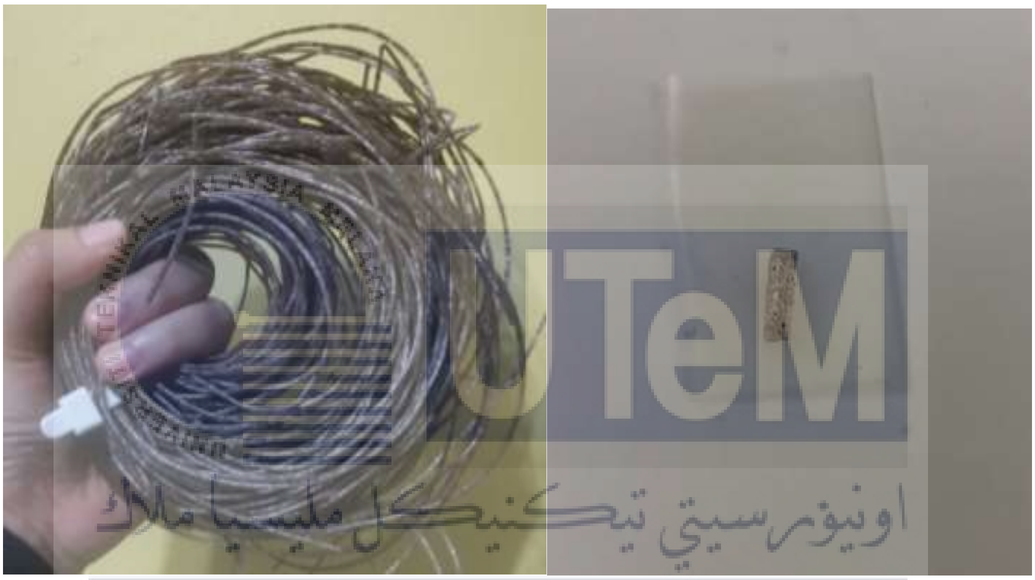
The filament that is in between 1.60-1.80 will be rolled into a spool while the ones that doesn't adhere to the requirements will be cut off. The process is repeated with several other compositions of Coconut fiber/Recycled Polypropylene resulting in several rolls of filaments ready to be printed. (Nasir , et al. 2022). The Figure 3.17 shows the produced filament that fit the requirement in between 1.60-1.80 mm.

Figure 3.18 Produced filament of the extrusion machine in accordance to the materials.

Figure 3.19 Flow of the filament extrusion process.

3.4 Microscopic Analysis

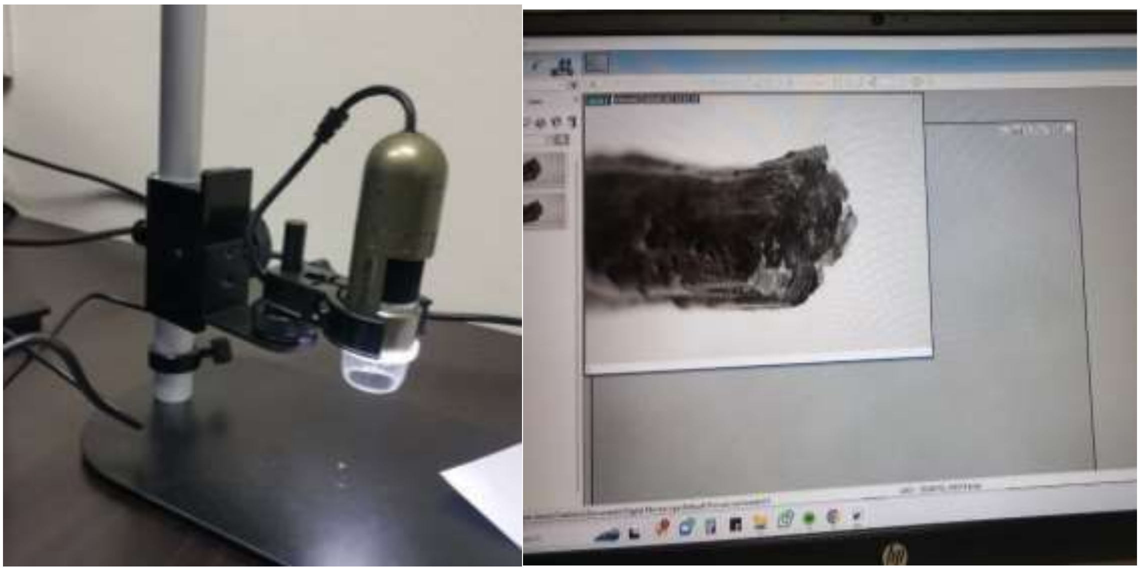
After the filament are produced, multiple test can be done on the trust such as microscopic analysis. Microscopic analysis can be done to dig deeper in the physical properties of the filament compositions. (Han, et al. 2022). In accordance of research, the higher the amount of the void in the filament can influence the mechanical properties. (Yusuf, et al. 2023). The process first begin by cutting the filament into a small piece to fit through the microscope. It is then stuck on the tape that is stuck to a paper. The figure 3.19 (a) below shows rolled up filament and (b) shows the cut up filament stuck onto a tape and paper.



(a) (b)

Figure 3.20 (a) Rolled up filament and (b) The cut up filament on tape and paper.

Then the microscope, Dino Lite is turned on and it is then connected to the laptop and the application needed to be installed in the laptop to be able to view the microscopic view of the filament. It is then the cut up filament is put under the microscope and then close up filament can be viewed. The Figure 3.20 (a) below shows the microscope that is used and (b) shows the open the application. Also the Figure 3.21 shows the process flow of microscopic analysis process.



(a) (b)

Figure 3.21 (a) The microscope that is used and (b) The open the application.

Figure 3.22 The process flow of the microscopic analysis process of the filament.

3.5 Water Absorption Test

The water absorption test follows the ASTM D570 standard. It is the most standard for most plastics. The standard states the function is to measure the percentage of water absorbed by the material. The parameters that must be fulfilled is by firstly to cut the filament into small lengths and then must be put into an oven for over an hour with the temperature of 105 ºC. The Figure 3.22 shows the cut up filament after being in the oven for an hour.

Figure 3.23 The cut up filament after being in the oven for an hour.

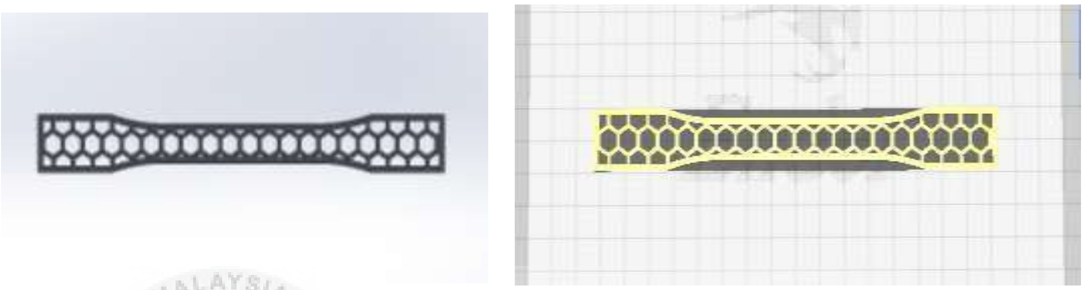
The filament is then weighted one by one in accordance to the weight percentage. The filament is put into tiny containers and labelled in accordance to weight percentage and whether it's treated and untreated filament. It is then submerged in distilled water for 24 hours and will be weighted once upon the 24 hours submersion are done. (Yusuf, et al. 2023). The figure 3.23 (a) shows the filament being weighted before being submerged in the water and (b) shows the submerged filaments in the containers.

(a) (b)

Figure 3.24 (a) The filament being weighted before being submerged in the water and (b) The submerged filaments in the containers.

3.6 FDM Printing Sandwich Structure

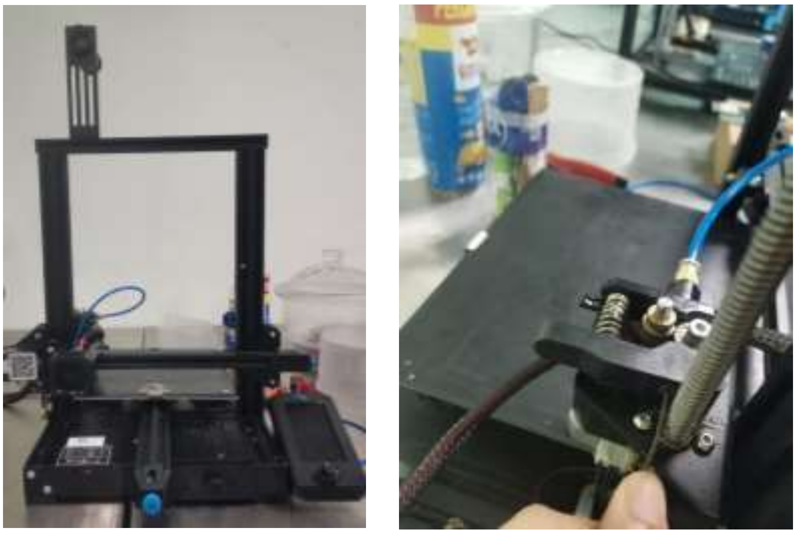
The sandwich structure that is chosen to be printed is a Honeycomb Sandwich Structure (HCSS). The printing uses a STL file made from Solidworks application and uses Ultimaker Cura for adjusting the STL files of the honeycomb structure. The Figure 3.24 (a) shows the Solidworks drawing of the specimen and (b) shows the stl file opened in Ultimaker Cura.



(a) (b)

Figure 3.25 (a) Solidworks drawing of the specimen (b) The stl file opened in Ultimaker Cura

The filaments are inserted through the 3D printer called Creality Ender 3 V2 and it'll be put into the filament slot and the hotbed of the 3D printer is calibrated as also for the printing calibrations and after all is done, the printing will begin. The Figure 3.25 (a) below shows the Creality Ender 3 V2 FDM printer and (b) shows the filament being inserted into the slot.



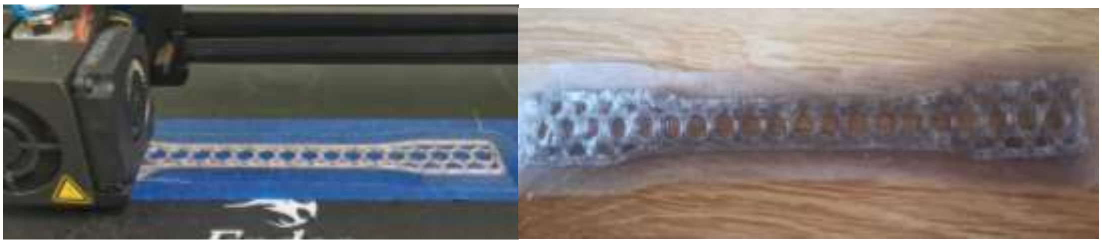
(a) (b)

Figure 3.26 (a) The Creality Ender 3 V2 FDM printer (b) The filament being inserted into the slot.

The hours one has to wait depends on the design. This process is again repeated several times with different weight percentage of Coconut fiber/Recycled Polypropylene weight percentage. Below is the Table 3.2 shows the printing parameter and process for FDM printing of the Honeycomb Sandwich Structure (Mohd Farhan Han, et al. 2022). There is also a Figure 3.26 (a) shows the HCSS specimen being printed and (b) shows the completed printing of HCSS specimen. To simply the process, the flow process is in the Figure 3.27.

Table 3.2 Printing Parameter of the 3D Printer

Parameter	Details	Value
Infill	Fill density	100%
	Fill pattern	Brim
Temperature	Left extruder	198 °C
	Platform	98 °C
Cooling	Fan Speed	2



(a) (b)

Figure 3.27 (a) The HCSS specimen being printed (b) The completed printing of HCSS specimen.

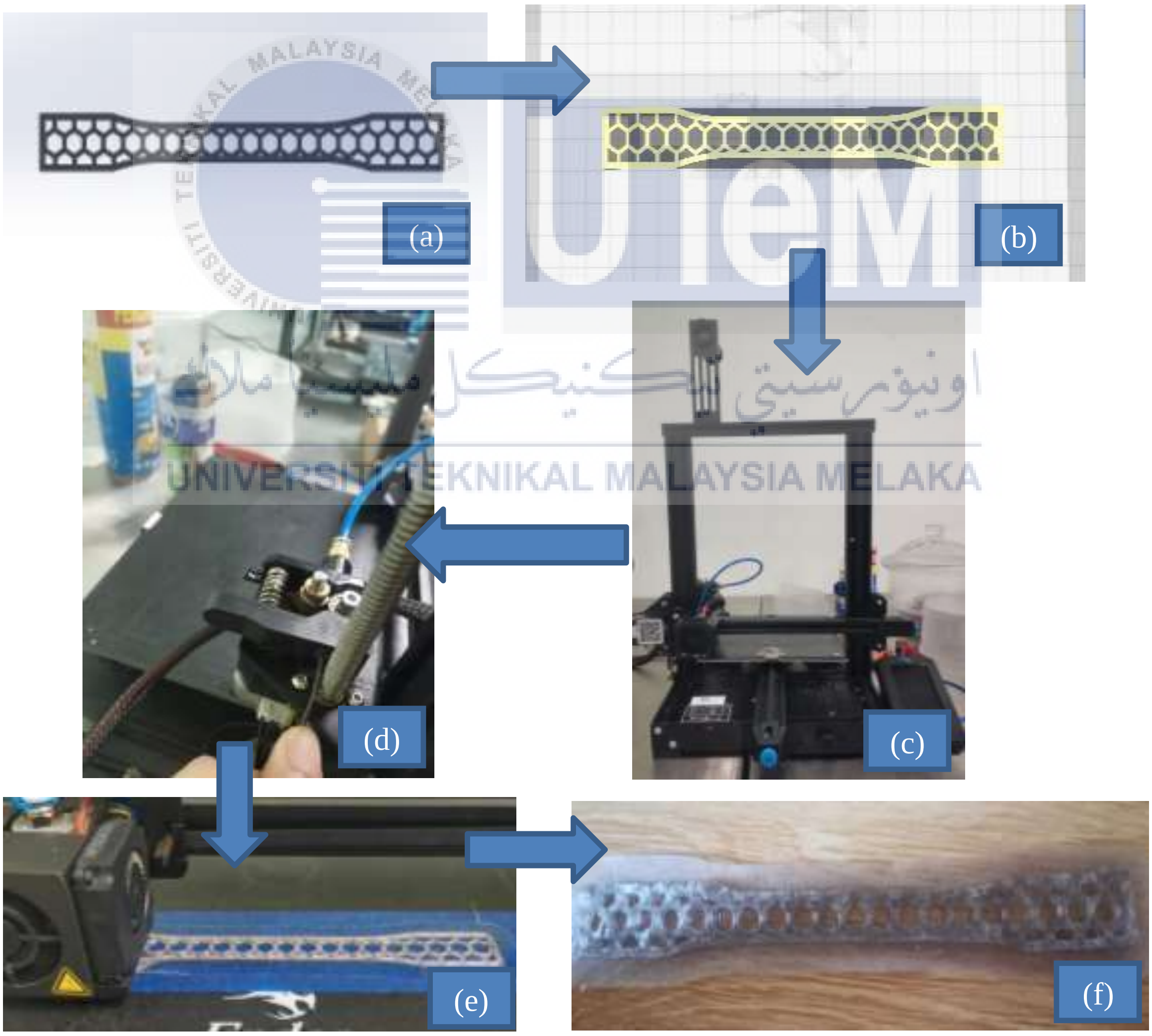


Figure 3.28 The process flow of FDM printing.

3.7 Testing of Sandwich Structure

Each of the printed composites will be tested with three standards test in regards of mechanical testing such as ASTM D638 which is a standard for tensile testing, ASTM D790 is standard for flexural testing for sandwich core and ASTM D570

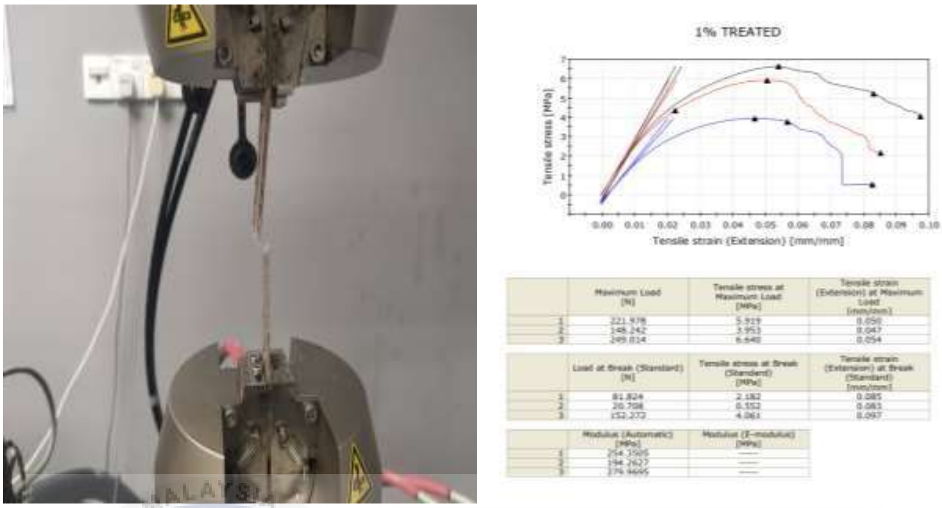
3.7.1 Tensile Test

The tensile characteristics of composite materials can be determined using the widely used testing standard ASTM D638. Composite materials are increasingly preferred by the aerospace and automotive industries due to their lightweight characteristics and high tensile strength, and they are being used to replace metals in many applications. Despite the fact that there are numerous varieties of composites, only those that are made of a polymer matrix and high-modulus fibers are covered by ASTM D638. The test will begin with the composite being put under a load the same as the flexural testing and the speed test of 5 min/mm until the sandwich structure breaks. The Figure 3.29 (a) below shows the machine and (b) shows the HCSS Coconut Fiber/ Recycled Polypropylene specimen.

(a) (b)

Figure 3.29 (a) The machine used(b) The HCSS Coconut Fiber/ Recycled Polypropylene specimen.

The results will be shown on the computer. The test will be repeated with other sandwich structures. (Mohd Latip 2017). The Figure 3.29 (a) shows the broken tensile specimen and (b) shows the results on the computer. For easier understanding of the process, a process flow has been added in Figure 3.30



(a) (b)

Figure 3.30 (a) The broken specimen (b) The result obtained on the computer

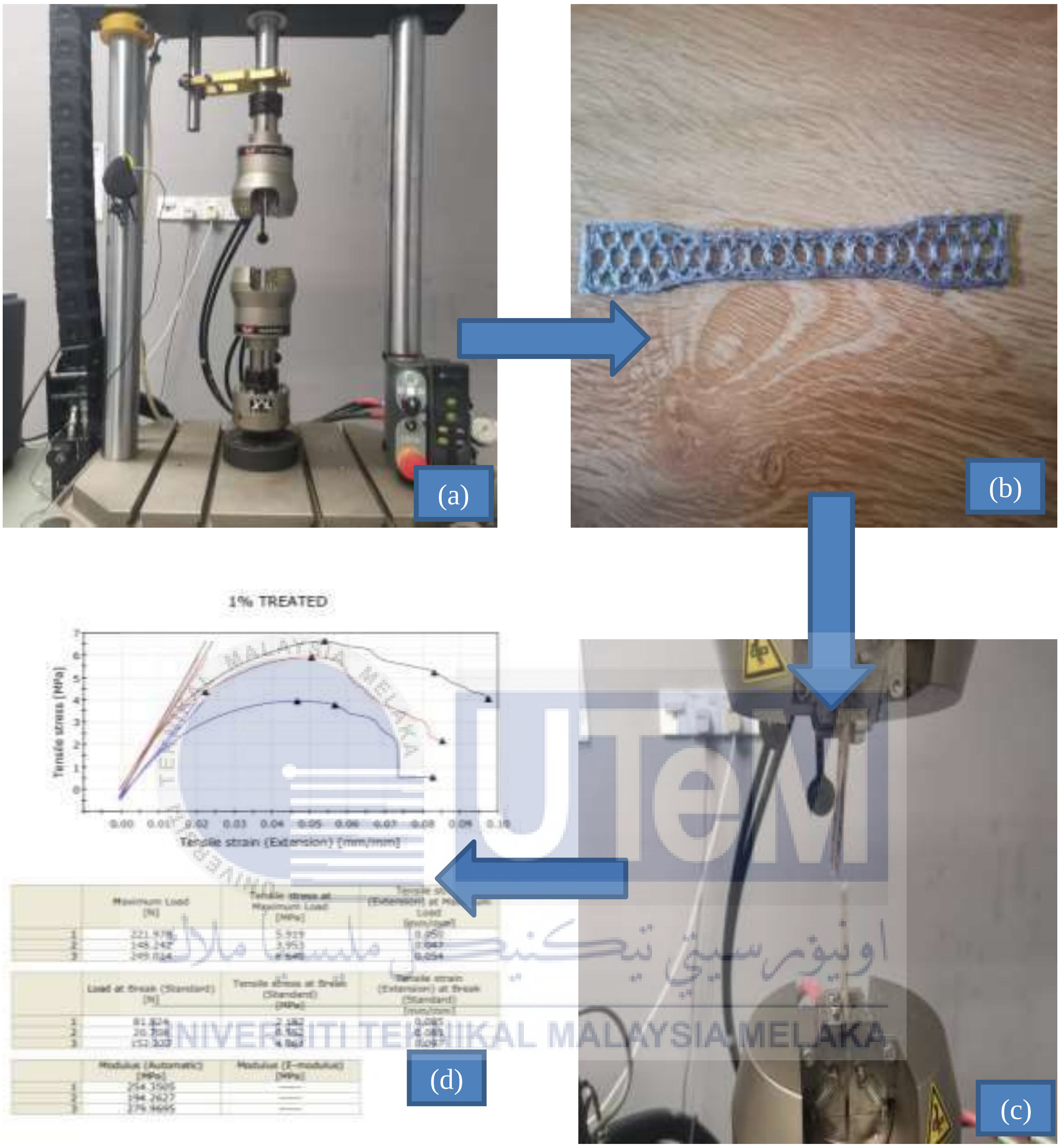


Figure 3.31 The process flow of tensile test.

3.7.2 Flexural Test

According to ASTM D790, which is a standardized method to measure the sandwich's flexural stiffness, the shear strength and shear modulus of the core, or the compressive and tensile strengths of the facings, flexure tests on flat sandwich construction may be carried out, the printed honeycomb sandwich structures will be put through flexural testing. Tests to quantify is it's flexural strength. First, the specimen must be marked in the middle. Figure 3.31 below shows the marked flexural specimen.

Figure 3.32 The marked specimen

To position the specimen properly, one must calculate it by putting a load of 73.8 kN load that will be applied to the sandwich core in the midst of the test. The distance between supporting pins by dividing the force with 2. The machine will then start the operation and the results are shown in the computer. (Pozzer, et al. 2020). The Figure 3.32 (a) shows the test starting and (b) shows the flexural result on the computer. Also for easier understanding, the Figure 3.33 is provided as a process flow of the flexural testing.

(a) (b)

Figure 3.33 (a) The test starting (b) The flexural result obtained on the computer

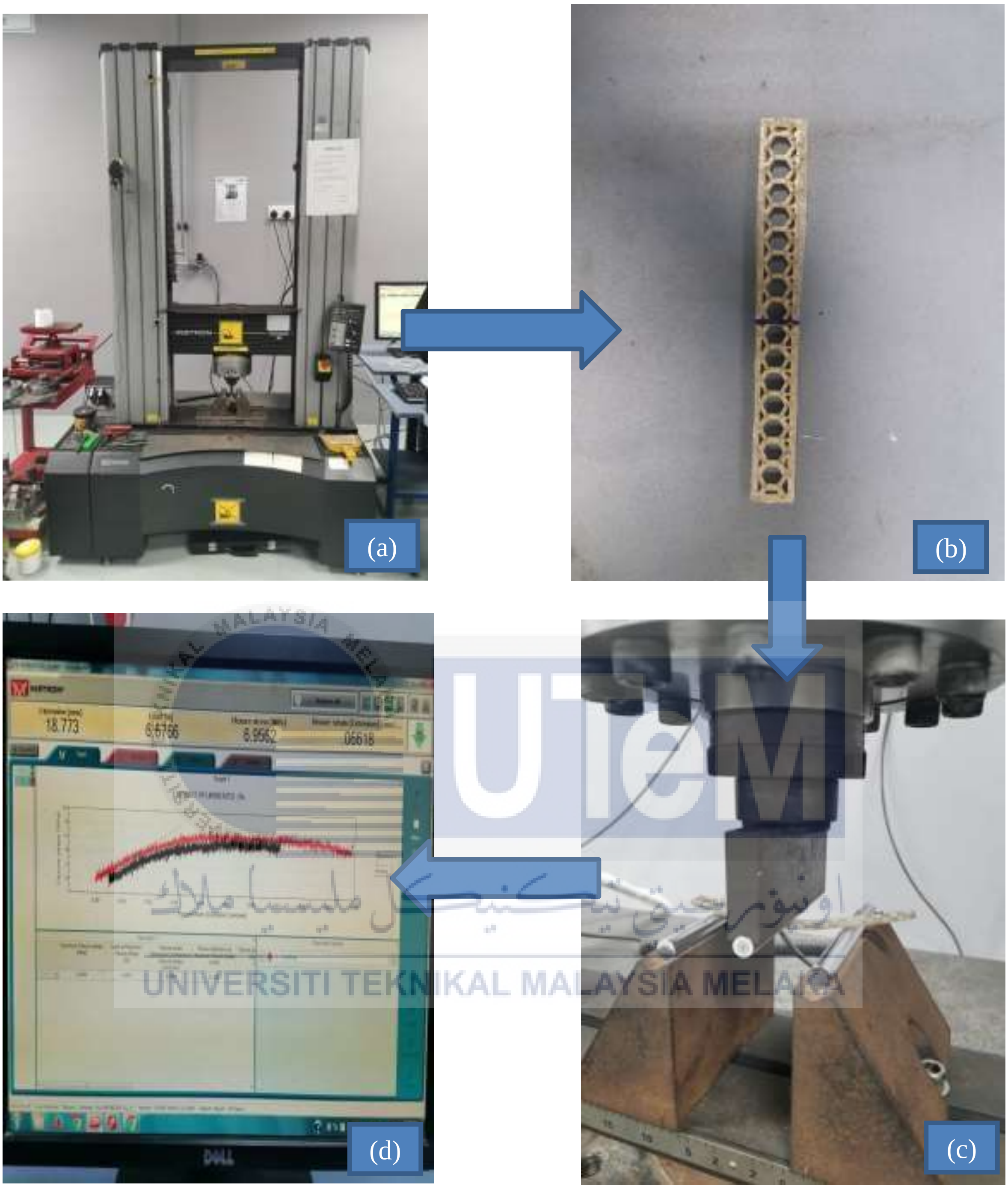


Figure 3.34 The process flow of flexural test.

3.8 Summary

To summarize this chapter, the presented methodology showcases the flow of the process in a clear way. The primary focus is the process flow of the whole study that must achieve each of the objective that is given in order to fully complete this study. The methods provided in this chapter also highlights on how important and rigorous in each step is in order to produce a high quality and accurate data. So in short, the Coconut Fiber/ Recycled Polypropylene Honeycomb Sandwich Structure (HCSS) using FDM process may have a lot of steps and parameters that must be followed but this is to ensure all of the data are accurate and in line with other studies that are provided.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses the result of each different type of tests and aspect of of the filaments. Each conducted tests are conducted using treated and untreated Coconut Fiber/Polypropylene with different weight percentage that uses FDM process to fabricate a Honeycomb Sandwich Structure (HCSS). The results that are obtained are substantiate with other with studies that are similar to this one.

4.2 Filament Produced

Based on the Figure 4.1 below, the filaments untreated (a) 1% wt (b) 3% wt (c) 5% wt and treated (d) 1% wt (e) 3% wt (f) 5% wt are shown in a roll. The untreated filament tend to have a more of a deep brown especially in the 5% wt whilst the treated filament has a more of a light brown tone even in the 5% wt. (Yusuf, et al. 2023) As the weight percentage of the fiber increases, the darker the filament is going to look. The surface of all of the filaments are smooth but for further analysis of the surface, microscopic analysis is way more detailed in terms of looking at the surface of the filament. The filament size is also in between 1.60-1.80 mm in terms of diameter and the filament can be slotted easily into the 3D printer.

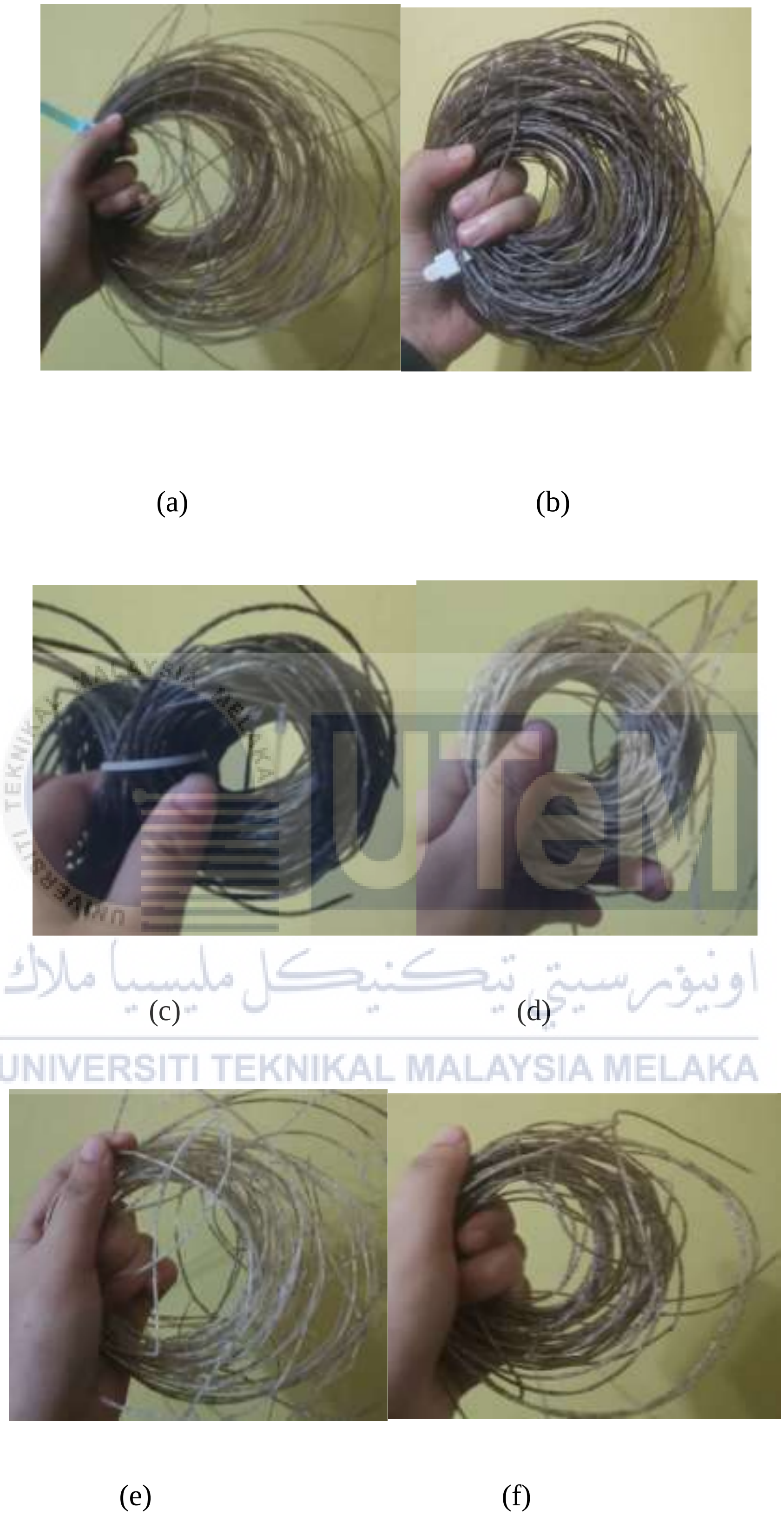


Figure 4.1 the filaments untreated (a) 1% wt (b) 3% wt (c) 5% wt and treated (d) 1% wt (e) 3% wt (f) 5% wt are shown in a roll

4.3 Microscopic Analysis

To further and deepen the analyze of the physical properties of the filament that is produced, microscopic analysis is performed on filaments that is cut. (Yusuf, et al. 2023) On the figure 4.2 below shows the surface of the untreated (a) 1% wt (b) 3% wt (c) 5% wt and treated (d) 1% wt (e) 3% wt (f) 5% wt. According to the result, the surface has some cutting marks in each of the composition filament. Although from what can be seen, there is barely any void can be seen on the surface of the filament. However, this is probably the fact that the microscope can only magnify up to 2x only and can barely see the void unlike using the Scanning Electron Microscopy (SEM) which can magnify up to 2000x. Thus the physical surface result isn't as accurate the surface can only be seen at the magnification of 2x.

(a) (b)

(c) (d)

(e) (f)

Figure 4.2 The surface of the untreated (a) 1% wt (b) 3% wt (c) 5% wt and treated (d) 1% wt (e) 3% wt (f) 5% wt.

4.4 Water Absorption Test

The result for water absorption is divided into two graphs as one showcase the weight of each filament before and after water absorption and the percentage of water absorption that occurred in each filament. Based on the Figure 4.3 below that showcase the weight of the weight of each filament before and after water absorption, it can be seen that the untreated coconut fiber absorbs a lot more water than the treated filaments.

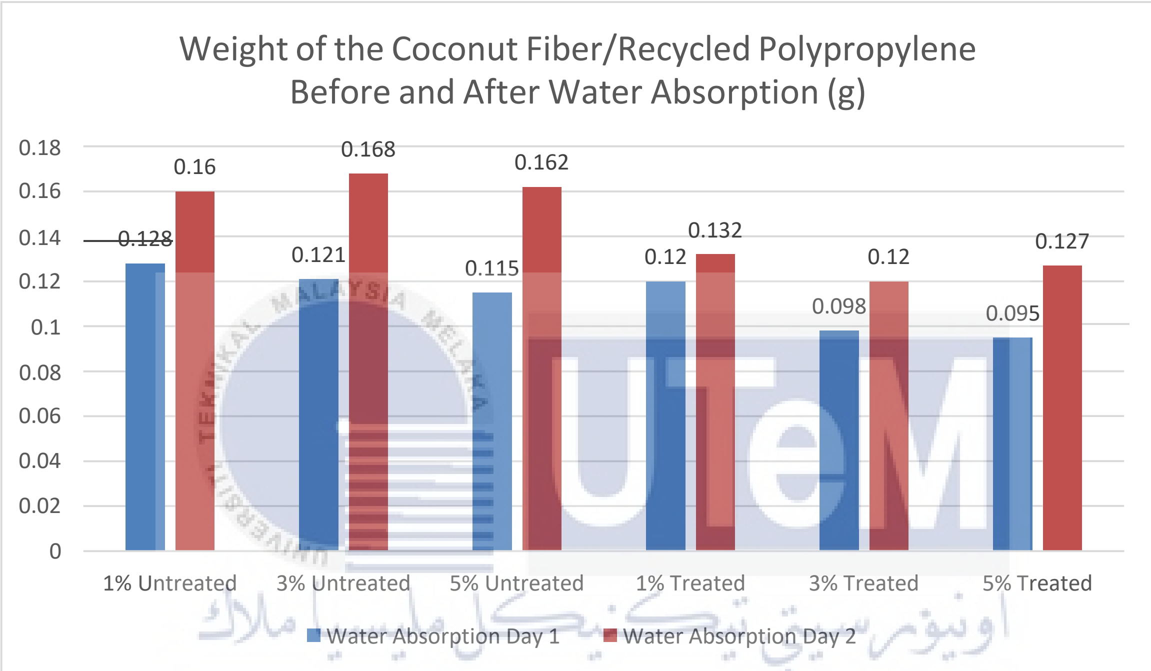


Figure 4.3 The weight of the weight of each filament before and after water absorption

In addition to the weight of the weight of each filament before and after water absorption, the percentage of water absorption of each filaments showcase on how much truly the water absorption occur in each composition of the filament. Based on the Figure 4.4, the highest percentage occur in the filament of the composition of the 5% wt whilst the lowest is the 1% wt in both treated and untreated filaments. This could be due to the higher the fiber composition, the higher the water absorption occurs. This can indicate that it is hydrophilic. (Yusuf, et al. 2023)

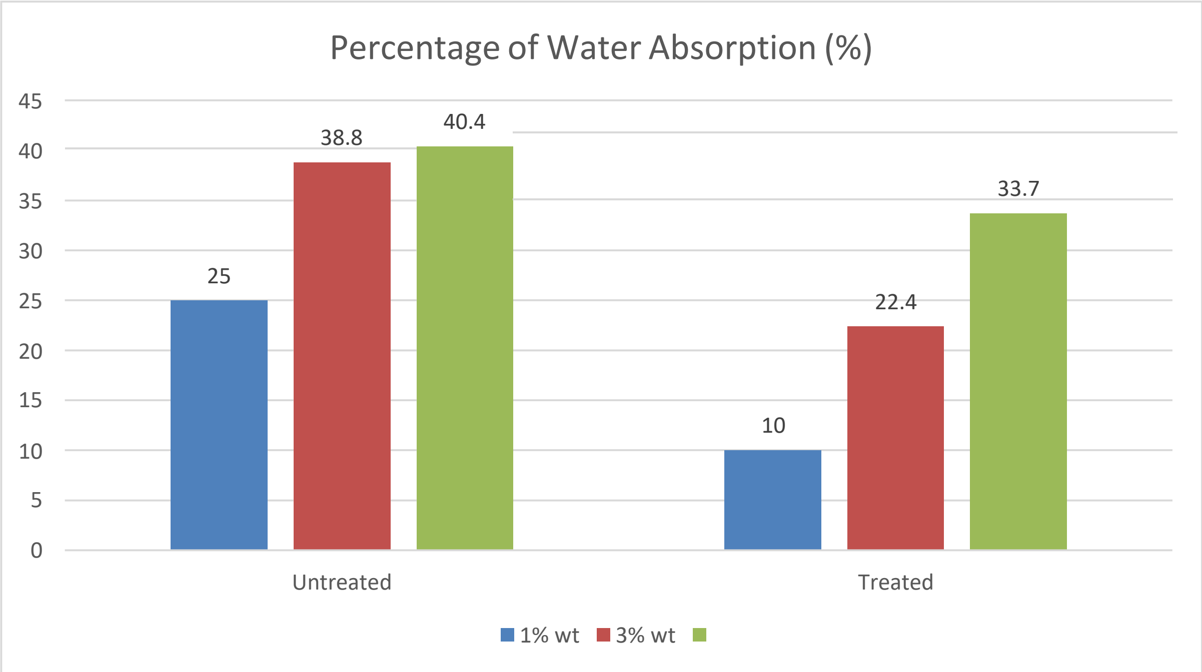


Figure 4.4 The percentage of water absorption of each filaments composition.

4.5 Tensile Test

Regarding the result for the tensile test from the Figure 4.5, there is a slight difference with the results obtained from the reference used, the highest shown in the reference is 3% wt for both treated and untreated while the lowest is 1% is the lowest. (Ahmad, et al. 2023). However, when it comes to the HCSS Coconut Fiber/Polypropylene, the 1% wt shows the highest for both untreated and treated and the lowest is 5% wt. This shows that the ductility of the HCSS Coconut Fiber/Polypropylene decreases as the fiber increases. This could be to natural fiber content increased, fiber-matrix adhesion decreased, and debonding happened during tensile deformation. The production of the voids was caused by debonding between the fiber and matrix, which made it simple for cracks to spread via the void-containing regions. Additionally, this could also indicate that the tensile strength of composites was impacted by the uneven distribution of natural fiber into composites. (Mohd Farhan Han, et al. 2022).

However the specimen is in the shape of a Honeycomb Sandwich Structure (HCSS), also be a factor of why the result is as such. According to the literature (Antony, Cherouat and Montay 2020), honeycomb core breaks catastrophically as it reaches the maximum load.

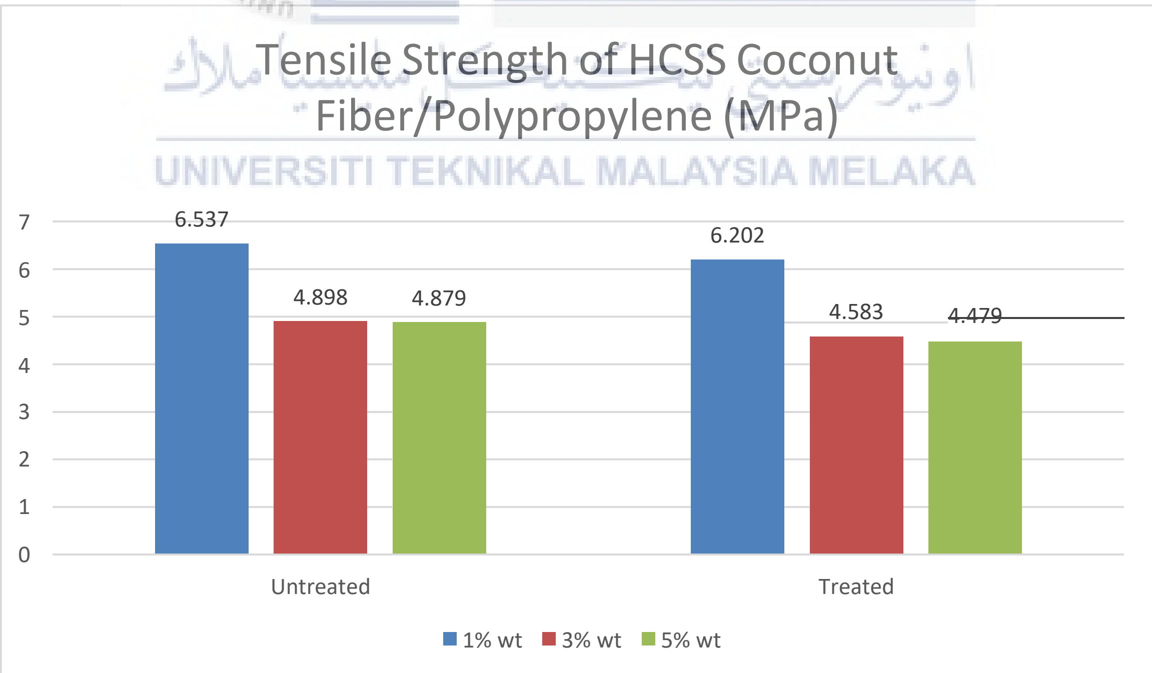


Figure 4.5 The tensile strength and Coconut fiber/Recycled Polypropylene

4.6 Flexural Test

The result obtained for flexural strength of Coconut fiber/Recycled Polypropylene from the figure 4.6 below shows that the more the percentage weight is added, the lower the flexural strength. (Ahmad, et al. 2023) The results below also indicate that the 1 wt%, treated Coconut fiber/Recycled Polypropylene has the highest flexural strength especially the untreated Coconut fiber/Recycled Polypropylene. Meanwhile, the 5 wt%, treated Coconut fiber/Recycled Polypropylene has the lowest flexural strength. (Jariwala and Jain 2019) As similar to tensile qualities, flexural strength rapidly declines with filler concentration, although stiffness has a distinct pattern of decline. This could be a factor from the Honeycomb Sandwich Structure (HCSS) as according to the literature (Antony, Cherouat and Montay 2020) Honeycomb Sandwich Structure provides bad flexural property compared to a normal tensile specimen.

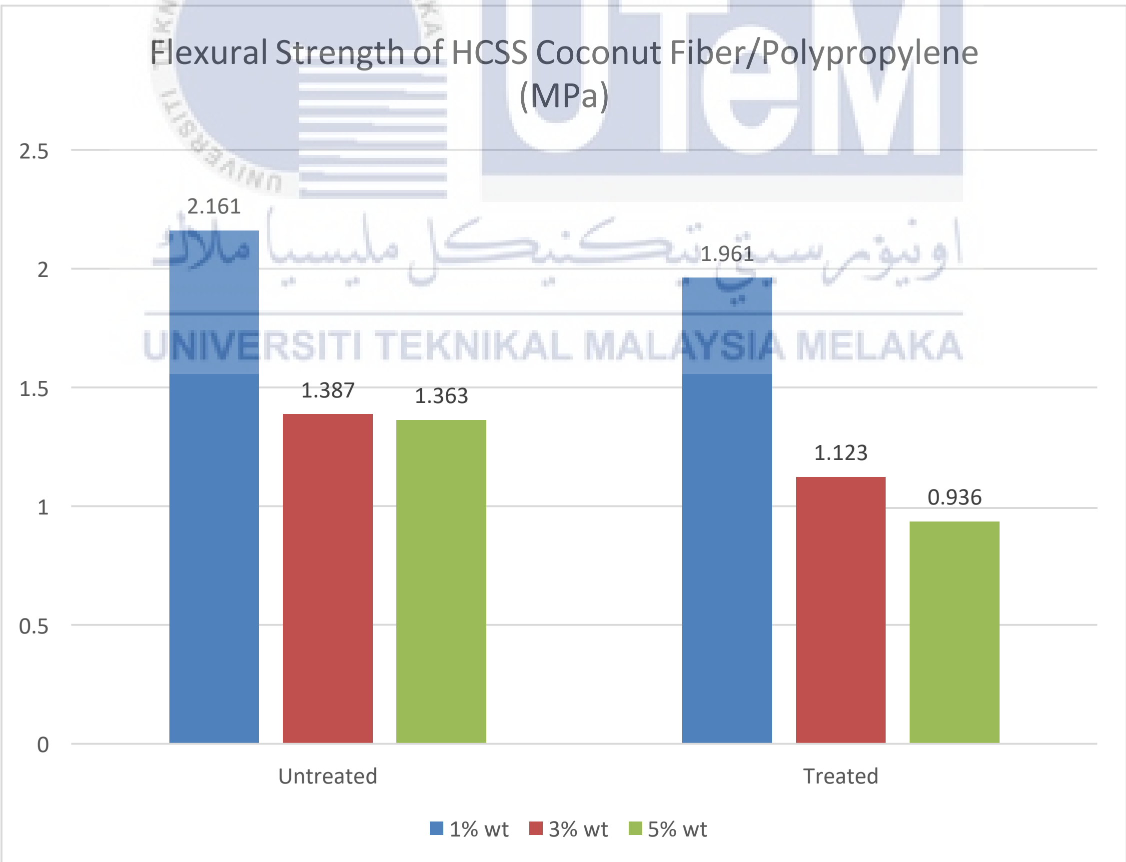


Figure 4.6 The flexural strength of the HCSS printed coconut fiber/polypropylene

4.7 Summary

To summarize the findings of the results, it can be concluded that the the fiber weight percentage of Coconut fiber have an significant impact towards the results due decrease of the thermoplastic matrix. Other factor that plays a role is the Honeycomb Sandwich Structure (HCSS) also contribute to the results especially in tensile and flexural as according to the literature as Honeycomb Sandwich Structure (HCSS) breaks catastrophically during the tensile test and Honeycomb Sandwich Structure (HCSS) has bad flexural strength. All of these factors plays a huge role in the results.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, the creation of a Honeycomb Sandwich Structure (HCSS) that utilize the Coconut fiber/Recycled Polyproplyne with FDM process has alot of potential when it comes to the material and the structure. As not only are the material is enviromentally friendly but also has shown to have potential to develop the material to be applicated in the industry as it's not only enviromentally friendly but also have good mechanical properties especially in the Coconut fiber/Recycled Polyproplyne that has underwent alkaline treatment.

However, contrary to the literature reviews, the results showed a more negative side. This could be a number of factors involved but from that is gathered and researched it could be that the alkaline treatment didn't go as well as it hoped to be. As according to (C.H, et al. 2022) by minimize treatment time and could improve the fiber alkaline treatment for the Coconut Fiber.So it could be that the Coconut fiber didn't respond well to treatment time that is used.

Nevertheless, this study still made it's contribution eventhough the results showed of a more negative side. With this contribution, further additional study must be done in order to further increase the mechanical properties of the Honeycomb Sandwich structure (HCSS) Coconut fiber/Recycled Polyproplyne with FDM process as the market are in demand for a better and more enviromentally friendly options.

5.2 Recommendation

For future recommendation, the accuracy of the data could be more accurate and enhanced as follows:

- The treatment time should be decreased in order gather a more accurate data for the treated Coconut Fiber

- The Coconut Fiber must be washed thoroughly after the treatment as the residue of alkaline treatment could still affect the data of the treated fiber.

- Use a more accurate machine as the machine that is used is more towards a metal specimen rather than a composite on.

- Print the samples on the same day as the 3D printer can also effect the Honeycomb Sandwich Structure data.

REFERENCES

Mazzanti, V., Malagutti, L., & Mollica, F. (2019). FDM 3D printing of polymers containing natural fillers: A review of their mechanical properties. In *Polymers* (Vol. 11,Issue 7).

Haque, M., Islam, N., Huque, M., Hasan, M., Islam, S., & Islam, S. (2010). Coir fiber reinforced polypropylene composites: Physical and mechanical properties. *AdvancedComposite Materials*, *19*(1), 91–106. https://doi.org/10.1163/092430409X12530067339325

Jariwala, H., & Jain, P. (2019). A review on mechanical behavior of natural fiber reinforced polymer composites and its applications. In *Journal of Reinforced Plastics andComposites* (Vol. 38, Issue 10, pp. 441–453). SAGE Publications Ltd. https://doi.org/10.1177/0731684419828524

Navaranjan, N., & Neitzert, T. (n.d.). *Impact Strength of Natural Fiber Composites Measured by Different Test Methods: A Review*.

Antony, S., Cherouat, A., & Montay, G. (2020). Fabrication and Characterization of HempFiber Based 3D Printed Honeycomb Sandwich Structure by FDM Process. *Applied Composite Materials*, *27*(6), 935–953. https://doi.org/10.1007/s10443-020-09837-z

Milosevic, M., Stoof, D., & Pickering, K. L. (2017). Characterizing the mechanical properties of fused deposition modelling natural fiber Recycled Polypropylene composites. *Journal of Composites Science*, *1*(1). https://doi.org/10.3390/jcs1010007

Arrigo, R., Battegazzore, D., Bernagozzi, G., Cravero, F., Ribero Pedraza, D. N., & Frache, A. (2022). Recycled PP for 3D Printing: Material and Processing Optimizationthrough Design of Experiment. *Applied Sciences (Switzerland)*, *12*(21). https://doi.org/10.3390/app122110840

Gopanna, A., Rajan, K. P., Thomas, S. P., & Chavali, M. (2019). Polyethylene and polypropylene matrix composites for biomedical applications. In *Materials for Biomedical Engineering: Thermoset and Thermoplastic Polymers* (pp. 175–216). Elsevier. https://doi.org/10.1016/B978-0-12-816874-5.00006-2

Gohar, S., Hussain, G., Ali, A., & Ahmad, H. (2023). Mechanical performance of honeycomb sandwich structures built by FDM printing technique. *Journal of Thermoplastic Composite Materials*, *36*(1), 182–200. https://doi.org/10.1177/0892705721997892

Ichim, M., Stelea, L., Filip, I., Lisa, G., & Muresan, E. I. (2022). Thermal and Mechanical Characterization of Coir Fiber–Reinforced Polypropylene Biocomposites. *Crystals*, *12*(9). https://doi.org/10.3390/cryst12091249

Mishra, L., & Basu, G. (2020). Coconut fiber: its structure, properties and applications. *Handbook of Natural Fibers: Second Edition*, *1*, 231–255. https://doi.org/10.1016/B978-0-12-818398-4.00010-4

Rowell, R. M. (2008). Natural fibers: types and properties. *Properties and Performance ofNatural-Fiber Composites*, 3–66. https://doi.org/10.1533/9781845694593.1.3

Han, S.N.M.F., Taha, M.M., Mansor, M.R. et al. Investigation of tensile and flexural properties of kenaf fiber-reinforced acrylonitrile butadiene styrene composites fabricatedby fused deposition modeling. J. Eng. Appl. Sci. 69, 52 (2022). https://doi.org/10.1186/s44147-022-00109-0APPENDICES

Ahmad, Mohd & Ishak, Mohamad & M.T., Mastura & Mustapha, Faizal & Leman, Z. & Irianto, Irianto. (2023). Mechanical, thermal and physical characteristics of oil palm (ElaeisGuineensis) fiber reinforced thermoplastic composites for FDM – Type 3D printer. Polymer Testing. 120. 107972. 10.1016/j.polymertesting.2023.107972.

Nasir, M. H. M., Taha, M. M., Razali, N., Ilyas, R. A., Knight, V. F., & Norrrahim, M. N.

F. (2022). Effect of Chemical Treatment of Sugar Palm Fibre on Rheological and Thermal Properties of the PLA Composites Filament for FDM 3D Printing. *Materials*,*15*(22). https://doi.org/10.3390/ma15228082

Thyavihalli Girijappa, Y. G., Mavinkere Rangappa, S., Parameswaranpillai, J., & Siengchin, S. (2019). Natural Fibers as Sustainable and Renewable Resource for

Development of Eco-Friendly Composites: A Comprehensive Review. In *Frontiers in Materials* (Vol. 6). Frontiers Media S.A. https://doi.org/10.3389/fmats.2019.00226

Kumar, S., Shamprasad, M. S., Varadarajan, Y. S., & Sangamesha, M. A. (2021). Coconutcoir fiber reinforced polypropylene composites: Investigation on fracture toughness and mechanical properties. *Materials Today: Proceedings*, *46*, 2471–2476. https://doi.org/10.1016/j.matpr.2021.01.402

Muhammad Arsyad, Nyoman Gede Wardana, Pratikto Yudy, & Surya Irawan. (2015). *Themorphology of coconut fiber surface under chemical treatment*.

Ariffadzilah Bin Mohd Latip, M. (2022). *PHYSICAL, MECHANICAL AND MORPHOLOGICAL PROPERTIES OF RECYCLED POLYPROPYLENE (PP) REINFORCED WITH COCONUT FIBER*.

Gelfuso, M. V., da Silva, P. V. G., & Thomazini, D. (2011). Polypropylene matrix composites reinforced with coconut fibers. *Materials Research*, *14*(3), 360–365. https://doi.org/10.1590/S1516-14392011005000056

Brachet, P., Høydal, L. T., Hinrichsen, E. L., & Melum, F. (2008). Modification of mechanical properties of Recycled Polypropylene from post-consumer containers. *WasteManagement*, *28*(12), 2456–2464. https://doi.org/10.1016/J.WASMAN.2007.10.021

.

Han, Syaza Najwa Mohd Farhan, et al. *Investigation of Tensile and Fexural Properties of Kenaf Fiber-Reinforced Acrylonitrile Butadiene Styrene Composites Fabricated by Fused Deposition Modeling*. 2022.

Yusuf, Yusliza, et al. *Development of 3D Printing FIlament Material Using Recycled Polypropylene (RPP) Reinforced with Coconut Fiber*. 2023.

F, Nur Ainin, et al. *An Overview of the Compression and Flexural Behaviours of Sandwich Composite Structure with 3D-Printed Core*. 2022.

Barbosa, Luiz Gustavo de Moura da Silva. *Analysis of Impact and Tensile Properties of Recycled Polypropylene*. 2017.

Ayrilmis, Nadir, et al. *Effects of the Face/Core Layer Ratio on the MechanicalProperties of 3D Printed Wood/Polylactic Acid (PLA)Green Biocomposite Panels with a Gyroid Core*. 2020.

Azzouz, Lyes, et al. "Mechanical Properties of 3-D Printed Truss-like Lattice Biopolymer Non-Stochastic Structures for Sandwich Panels with Natural Fibre Composite Skins." *Composite Structures*, vol. 213, Apr. 2019, pp. 220–230, https://doi.org/10.1016/j.compstruct.2019.01.103. Accessed 10 Jan. 2024.

Saba, N., et al. "A Review on Dynamic Mechanical Properties of Natural Fibre Reinforced Polymer Composites." *Construction and Building Materials*, vol. 106, Mar. 2016, pp. 149–159, https://doi.org/10.1016/j.conbuildmat.2015.12.075. Accessed 10 Jan. 2024.

Appendix A: Gantt Chart PSM I

		Week													
No	Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Title given and research begins														
2	Summarize references that are found														
3	Discuss and review problem statement														
4	Discuss and review objective and scope														
5	Research i and implement in report n regards for chapter 2														
6	Discuss with supervisor and rework														
7	Research in regards for chapter 3 and 4 and implement in report														
8	Discuss with supervisor and rework														
9	Start buying the materials														
10	Materials arrives														
11	Complete PSM1 Report														
12	Prepare for presentation														
13	PSM1 Presentation														

Planning	Actual

Appendix B: Gantt Chart PSM II

No	Task	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Wash the fibers and dry it														
2	Cut the fiber and crush it														
3	Sieve the coconut fiber into >125 µm														
4	Treat the sieved coconut fiber and dry in the oven														
5	Hotpress the treated and untreated fiber with recycled polypropylene														
6	Cut and crush the hotpressed composites														
7	Crushed composite is the inserted into extruder to turn into filaments														
8	FDM printing of the composite filaments														
9	Flexural testing														
10	Tensile testing														
11	Water absorption testing														
12	Start report PSM 2														
13	Discuss and rework reports														
14	Submit PSM 2 documents														
15	Prepare for Presentation PSM 2														
16	PSM 2 Presentation														

Planning	Actual

Thesis Nas.pdf

ORIGINALITY REPORT

21%	16%	14%	11%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	eprints.utem.edu.my Internet Source	2%
2	Submitted to Universiti Teknikal Malaysia Melaka Student Paper	1%
3	Mokrini, A.. "Partially fluorinated proton exchange membranes based on PVDF-SEBS blends compatibilized with methylmethacrylate block copolymers", Journal of Membrane Science, 20061020 Publication	1%
4	umpir.ump.edu.my Internet Source	1%
5	dokumen.pub Internet Source	1%
6	Submitted to Fr Gabriel Richard High School Student Paper	1%
7	jctjournal.com Internet Source	1%

How much of this submission has been generated by AI?

0%

of qualifying text in this submission has been determined to be generated by AI.

Caution: Percentage may not indicate academic misconduct. Review required.

It is essential to understand the limitations of AI detection before making decisions about a student's work. We encourage you to learn more about Turnitin's AI detection capabilities before using the tool.

Frequently Asked Questions

What does the percentage mean?
The percentage shown in the AI writing detection indicator and in the AI writing report is the amount of qualifying text within the submission that Turnitin's AI writing detection model determines was generated by AI.

Our testing has found that there is a higher incidence of false positives when the percentage is less than 20. In order to reduce the likelihood of misinterpretation, the AI indicator will display an asterisk for percentages less than 20 to call attention to the fact that the score is less reliable.

However, the final decision on whether any misconduct has occurred rests with the reviewer/instructor. They should use the percentage as a means to start a formative conversation with their student and/or use it to examine the submitted assignment in greater detail according to their school's policies.

How does Turnitin's indicator address false positives?
Our model only processes qualifying text in the form of long-form writing. Long-form writing means individual sentences contained in paragraphs that make up a longer piece of written work, such as an essay, a dissertation, or an article, etc. Qualifying text that has been determined to be AI-generated will be highlighted blue on the submission text.

Non-qualifying text, such as bullet points, annotated bibliographies, etc., will not be processed and can create disparity between the submission highlights and the percentage shown.

What does 'qualifying text' mean?
Sometimes false positives (incorrectly flagging human-written text as AI-generated), can include lists without a lot of structural variation, text that literally repeats itself, or text that has been paraphrased without developing new ideas. If our indicator shows a higher amount of AI writing in such text, we advise you to take that into consideration when looking at the percentage indicated.

In a longer document with a mix of authentic writing and AI generated text, it can be difficult to exactly determine where the AI writing begins and original writing ends, but our model should give you a reliable guide to start conversations with the submitting student.