EXPERIMENTAL ANALYSIS ON MECHANICAL PROPERTIES OF PINEAPPLE LEAF REINFORCED POLYESTER RESIN

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

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Faculty of Mechanical and Manufacturing Engineering Technology

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A thesis submitted
in fulfilment of the requirements for the degree of
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DECLARATION

I declare that this project entitled "Experimental Analysis On Mechanical Properties Of Pineapple Leaf Reinforced Polyester Resin", it is the result of my own research except as cited in the references. It has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature :

Name : *SIVANESWARAN A/L MANOKARAN.*

Date : 9 January 2023

APPROVAL

I, at this moment, declare that I have checked this project. In my opinion, this project 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. ISKANDAR BIN WAINI.*

Date : 9 January 2023

DEDICATION

Thanks to God for providing me with the strength, patience, direction, and knowledge to accomplish this study. I am grateful to God Almighty for allowing me to join this programme. A special award, this thesis I dedicated to my parents, Manokaran A/L Vadiveloo and Aravalli A/P Gurusamy, who have always been there for me. Finally, I'd like to thank my supervisor, Dr. Iskandar Bin Waini and my co-supervisor, Dr. Khairum Bin Hamzah, for all his help, guidance, and a advice in completing this thesis.

ABSTRACT

Being biodegradable and user-friendly, the unique composite formed of natural fibres has amazing potential for weight reduction in materials while also lowering the cost of materials due to its low cost. However, natural fibres has a lower strength than polyester resin 100 percent, which is a disadvantage. Many research investigations have been conducted on two-hybrid composites that include natural and synthetic fibres. A fresh investigation of the mechanical behaviour of pineapple leaves reinforced by polyester resin (PLPR) composites was reported in the current work. Five eco-friendly ratios of natural and synthetic materials were produced utilising the mixing composites, which were constructed using the hand lay-up technique. These composites have the following weight ratios: 20% pineapple leaf and 80% polyester resin (20PL80PR), 40% pineapple leaf and 60% polyester resin (40PL60PR), 50% pineapple leaf and 50% polyester resin (50PL50PR), 60% pineapple leaf and 40% polyester resin (60PL40PR), and 80% pineapple leaf and 20% polyester resin (80PL20PR). Tensile, flexural, and impact tests were used to investigate the mechanical properties of the pictures of the powdered pineapple leaf obtained using a stereo microscope. Statistics were used to assess the data that had been collected. The mechanical behaviour of the PLPR composites according to the five ratios is seen through numerical calculations and graphical examples. The mechanical behaviour of PLPR composites will have an impact on the various ratios. The results showed that the composite with 60% pineapple leaf had better mechanical behaviour than the other composites due to the synergistic effect of reinforcements.

ABSTRAK

Sebagai terbiodegradasi dan mesra pengguna, komposit unik yang terbentuk daripada gentian semula jadi mempunyai potensi yang menakjubkan untuk pengurangan berat bahan di samping mengurangkan kos bahan kerana kosnya yang rendah. Walau bagaimanapun, gentian semulajadi mempunyai kekuatan yang lebih rendah daripada resin poliester 100 peratus, yang merupakan kelemahan. Banyak penyiasatan penyelidikan telah dijalankan ke atas komposit dua-hibrid yang termasuk gentian asli dan sintetik. Penyiasatan baru tentang tingkah laku mekanikal daun nanas yang diperkuat oleh komposit resin poliester (PLPR) telah dilaporkan dalam kerja semasa. Lima nisbah mesra alam bagi bahan semula jadi dan sintetik telah dihasilkan menggunakan komposit pencampuran, yang dibina menggunakan teknik letak tangan. Komposit ini mempunyai nisbah berat berikut: 20% daun nanas dan 80% poliester resin (20PL80PR), 40% daun nanas dan 60% poliester resin (40PL60PR), 50% daun nanas dan 50% poliester resin (50PL50PR), 60% nanas daun dan 40% resin poliester (60PL40PR), dan 80% daun nanas dan 20% resin poliester (80PL20PR). Ujian tegangan, lentur dan hentaman digunakan untuk menyiasat sifat mekanikal gambar daun nanas serbuk yang diperoleh menggunakan mikroskop stereo. Statistik digunakan untuk menilai data yang telah dikumpul. Kelakuan mekanikal komposit PLPR mengikut lima nisbah dilihat melalui pengiraan berangka dan contoh grafik. Kelakuan mekanikal komposit PLPR akan memberi kesan kepada pelbagai nisbah. Keputusan menunjukkan bahawa komposit dengan 60% daun nanas mempunyai tingkah laku mekanikal yang lebih baik daripada komposit lain kerana kesan sinergistik tetulang.

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This investigation could not have been completed without the knowledge of Dr Iskandar Bin Waini, my supervisor. A debt of gratitude is also owed to Dr Khairum Bin Hamzah, my co-supervisor, for pointing out and providing us with the guides for our framework.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

ANOVA	-	Analysis of varience
ASTM	-	American Society for Testing and Materials
DOA	-	Departure of agriculture
D,d	-	Diameter
etc	-	Other similar things
GFREC	-	Glass fibre reinforced epoxy composite
HFREC	-	Hybrid fibre reinforced epoxy composite
J	-	Joule
Nfs	-	Natural fibers
Mt	-	Mechanical testing
MPa	-	MegaPascal
PLA	-	Polylactic acid
PL	-	Pineapple leaf
PR	-	Poyetser resin
PLPR	-	Pineapple leaf reinforced polyester resin
PALF	-	Pineapple leaf fiber
RFREC	-	Ramie fibre reinforced epoxy composite
RM	-	Ringgit Malaysia
UP	-	Union pacific

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Nowdays, there are very high demand for eco-friendly materials based on recycling is in line with the industrial demand that affects the potential of the characteristic features from it. The development of technology and population, as well as changes in habits in society, have resulted in a substantial rise. Therefore, the issue of poor management becomes one of the significant factors faced by the modern society of this compilation. Waste to the environment can help the industry produce an environmentally friendly product.

Natural wastes such as agricultural and industrial waste are too much in Malaysia. The waste can be recycled and reused. The increase in population will indirectly increase waste. In addition, there is also waste that does not decompose easily and will remain in the environment. In Malaysia, there are various environmental materials such as oil palm, wood, rice, coconut, rubber, pineapple leaf, etc. This material can potentially replace the primary material from the waste due to its hard and non-perishable composition.

Agricultural waste from agro-based industries such as palm oil, rubber, and wood processing plants has more than tripled. Selangor, Perak, and Johor account for 65.7 percent of all identified pollution sources in the manufacturing and agro-based sectors (DOE, 2010).

Increasing pineapple demand contributes to massive pineapple production, resulting in large waste. Approximately 80% of pineapple parts are discarded during pineapple processing, transportation, and storage, including the crown, peels, leafs, core, and stems. Malaysia, one of the leading agricultural commodity producers in Southeast Asia, produces 335,488 tonnes of pineapple, as well as 67,098 and 137,550 tonnes of leaf and peel wastes. These wastes contain high levels of moisture, sugar, albumins, lipids, and vitamins that are susceptible to microbial degradation, contributing to environmental issues.

Material required for this composite is pineapple leaf. Pineapple leaf composite is more attractive because of their incredible strength, small weight, and less density. They are ecological and eco-friendly. Pineapple leaf is a common natural filler found in forest nations. For example, Asian countries, as Indonesia, Malaysia, Thailand, and India are among the countries involved. Pineapple leaf are also easy to obtain, low cost and easy to process. Pineapple plantations occupy a large portion of Malaysia's agricultural area. The operations of the Malaysian pineapple industry contribute a little amount to the Malaysian economy, with a 0.08 percent contribution to export revenues in 2008.

In Malaysia, pineapple is a former industrial crop that has been around for nearly a century. Pineapple cultivation provides a lucrative income for growers, especially when high planting density is established on the farm and cultivars with a stable yield and high disease resistance are used. The Department of Agriculture (DOA) reported that 272,570 (Mt) of pineapple were produced throughout the year in 2015. Table 1.1 shows the details of pineapple planted area, production, and value of production.

Table 1.1 Planted area and harvested area, production, and value of production of pineapple in Malaysia, 2015-2017

YEAR	**Planted Area (Ha)**	**Harvested Area (Ha)**	**Percentage of Harvested Area (%)**	**Production (Mt)**	**Value of Production (RM)**	**Average Yield (Mt/Ha)**	**Potetial Production (Mt/Ha)**
2015	10,847.0	8,975.3	82.7	272,570.0	386,140,8	30.4	62.0
2016	13,148.9	10,354.1	78.7	391,714.4	515,248.7	37.8	62.0
2017	12,898.44	10,130.76	78.54	340,721.9	668,666.8	33.63	62.0

Among thermosetting polymers, polyester resins are the most prevalent used in our daily lives and in industry. Polyester resins are a popular type of thermosetting resin used in the coatings and adhesives industries, with global production estimated at 2 million tons in 2010. Polyester resins are typically cured by thermal, chemical treatments and irreversibly cross-linked products. The cured polyester resins have remarkable physicochemical qualities, including outstanding chemical resistance and mechanical attributes. Consequently, polyester resin is a binder used to bond glass fiber and pineapple leaf.

Natural fibers have several advantages over synthetic fibers, including eco-friendliness, biodegradability, lower density, and abundant availability. At the same time, a few disadvantages include strong polarity, greater hydrophilicity due to the presence of hydroxyl groups, and limited compatibility with polymer-derived matrices (particularly thermos-plastics). However, the excellent price-performance ratio at low weight, combined with the environmentally friendly character, became a critical factor in natural fiber acceptance in large volume engineering markets such as the automotive and construction industries (Kumar et al., 2020).

According to one study, the addition of PALF filler to the epoxy matrix resulted in an increase in strain value for most of the filler loading compared to the base matrix. This behaviour is caused by the composite's decreased plasticity and increased elasticity due to the reinforcement of PALF fillers in the epoxy matrix. The inferior plasticity of the composite reduced its brittleness, resulting in more excellent elongation at break. The lowest and highest tensile strain values are obtained for 10% and 5% filler loading, respectively, at different crosshead speeds (Kumar et a., 2020).

Another study compares the tensile properties of jute, pineapple leaf, and glass fiber. Reinforced hybrid composites were created by ASTM D 638M. The composite specimens were 165 mm long, 12.7 mm wide, and 3 min thick. The specimens were tested using a

Tensile testing machine supplied by Associated Scientific Engg. Works, New Delhi, at a crosshead speed of 2.5 mm/min. (Indra Reddy et al., 2018).

Finally, the flexural strength and tensile strength comparison revealed a similar pattern. The addition of glass fibre increased flexural strength by 89.14 percent, and the flexural strength of the hybrid specimen increased by 164.66 percent when compared to the PALF-vinyl ester specimen. This demonstrates that adding glass increased the shear resistance of the composite, reducing shear failure. In general, the hybrid composite attribute is determined by the properties of the reinforcement (Zin et al., 2018).

1.2 Problem Statement

Malaysia's manufacturing industry has recently grown. As a result, the use of materials in the manufacturing industry, as well as in everyday life, will increase. The manufacturing industry's high demand for recycled materials will continue. There will also be an increase in demand for coarse aggregate.

It is also not appropriate in this situation to realy solely on one source because it is feared that there will be a shortage and that we will be unable to meet demand in the future. As a result, some new alternatives must be developed to cover the future. Several studies have been conducted as a result of the observations made in order to meet the material requirement. A large number of materials are produced from. recycled or from environmentally friendly such as stones, discarded durian skins, and so on.

In this study, pineapple leaf was used as an alternative made from environmentally friendly waste. Most Malaysians consume pineapple daily. Pineapple leaves are frequently thrown away and burned. Because of its complex and not easily damaged composition, pineapple leaf has the potential to replace waste aggregate.

Furthermore, the recent lack of garbage collection points is a major source of environmental issues, and garbage disposal is becoming increasingly important as natural resources become scarce. Furthermore, the properties of various raw materials. Cutting performance is a problem for eco-composite materials. Natural materials have multiple properties such as strength and elongation. Then, to determine an excellent composite ratio, it must be compared to the tested material. The strength of the pineapple leaf material in relation to the goal to be achieved.

1.3 Research Objective

The primary goal of this study is to look at the mechanical properties of pineapple leaf waste that has been strengthened with polyester resin. The following are the specific objectives follows:

a) To fabricate the pineapple leaf composite using hand lay-up method.

b) To perform the mechanical testing of pineapple leaf reinforced polyester resin.

c) To determine the significant differences in different ratio of the reinforced composites by using the statistical analysis

1.4 Scope of Research

The focus of this study will be on the mechanical properties of pineapple leafs reinforced with polyester resin. Pineapple leaf and polyester resin are used in this project. In order to fabricate the pineapple leaf recycling trash. The hand-mixed lay-up technique will be used to create this pineapple leaf. The procedure of cutting specimens is to be tested using a cnc router machine. Tensile, impact, and flexural testing will be used to evaluate the mechanical properties of the experimental material. Anova will be used to analyse the data from the experiment specimen. Based on three separate testing processes, we'll choose the best result for quality, strength of material ratio, and mechanical properties of specimen material.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

It was a description of the development of the composition of natural material from the waste material, such as pineapple leaf. In addition, the strength of pineapple leaf is also discussed in this chapter. My study had focused on the result of defects on the agro-culture waste material by different processes. Therefore, discuss two ways of drying process of waste material. The main analysis of the research is to observe the most strength and calculate quality defect using ANOVA.

2.2 Composite

Composite materials with natural fibres are those in which at least some of the reinforcing fibres are derived from resources that are carbon-neutral and renewable, such as plants or wood. The composite is referred to as a polymer matrix composite if the matrix is a polymer. The continuous stage is referred to as the matrix, but the intermittent phase is called the reinforcement since it is often tougher and stronger than the continuous stage. Polymeric, metal, or even ceramic might be used to make the matrix. Over the past ten years, the usage of green materials has become more widespread. There are sincere efforts being made around the world to find bio-based resources and biodegradable products that take climate change mitigation seriously (Saha et al., 2021).

2.3 Bio composite

Bio composite products made with reinforcing with natural cellulose fibres and a in matrix recently piqued the interest of researchers. Its availability, renewability, high specific mechanical strengths, degradability, and environmental friendliness piques their interest. (Bharath et al., 2018). Natural and synthetic polymers, sugar, protein, metals, and nano-carbons, among other organic and inorganic components, are also included in bio composites. Films, membranes, moulding, coating, particles, and other materials Bio composites include fibers, foams, and other materials.

2.3.1 Properties of Bio Composite

New materials, goods, and techniques are being developed as a result of industrial ecology, eco-efficiency, and green chemistry. Sustainability, industrial ecology, eco-efficiency, and green chemistry are advantages of bio composites created from solar and renewable resources. These benefits are driving the development of new materials, products, and processes. Over Bio composites have seen significant growth in the residential sector over the last decade. Materials for construction, aerospace applications, circuit boards, and automotive applications. However, their application in other areas has been limited (Alix et al., 2008).

Widespread availability, high stiffness and tensile strength, low cost, and well-developed methods for fibre extraction from renewable resources are a few advantages. Bio composites can be designed to fit a wide range of applications. applications in industry, which is one of its primary benefits (Amiandamhen et al., 2020).

Natural fibers contain cellulose, hemicellulose, lignin, pectin, waxes, and other extractives that are water soluble. However, they have some limitations when used in bio composite materials. Natural fibers' moisture sensitivity and variable fiber properties, as well as the fundamental incompatibility of hydrophilic fibers and hydrophobic matrices, are significant limitations to their use in bio composites. Figure 2.1 view the application of natural fibers. Non-food fibers such as kenaf, hemp, flax, and sisal have all found commercial success in constructing bio composites for the automotive industry at the current level of technology (Bharath and Basavarajappa 2016).

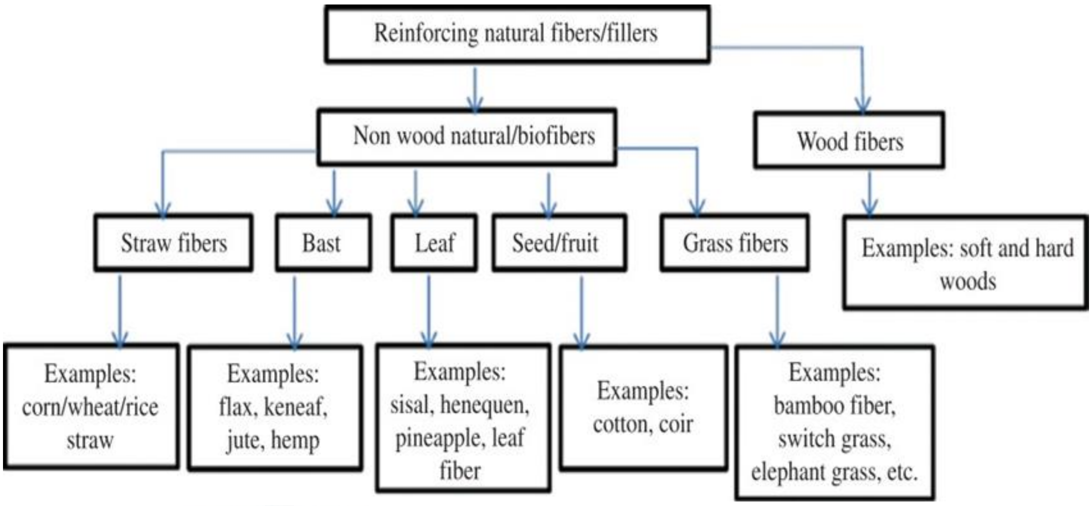


Figure 2.1 The application of natural fibers (Bharath and Basavarajappa, 2016).

2.4 Natural Fiber composite

Composite natural fiber is made from plants and animals. In addition, natural fiber. The construction industry, which is the largest user of composite materials, is increasingly associated with composite. Natural fiber polymer composites, such as jute, oil palm, sisal, kenaf, coconut, and flax, are made up of a polymer framework implanted with high-strength common threads (Jain and Tripathi, 2014).

A bio composite matrix and epoxy resin fibers were used in a study to evaluate natural fiber composites. Epoxy resin fibers were made from jute, sisal, coconut, betel nut, and pineapple fibers. To form a helmet shell structure, they use the technique of positioning their hands in the correct positions. Servers require the mechanical qualities of their artificial Bio composites, such as impact and bending strength. Bio-composite helmets were used to investigate the impact of weight loss. Further optimization of natural fiber volume fractions led to the conclusion that bio-composites could be a viable option for helmets (Bharath et al. (2018).

This article looked at how natural fiber reinforced polymer matrices worked with three different types of natural fiber fabrics. Engineering characteristics and creep deformation Composites are defined by their reliance on the type and orientation of the fabric. The mechanical capabilities of the textile bio reinforced based composites evaluated were comparable to those of various common building materials, according to their findings. It was demonstrated that the method might be used to speed up the collection and analysis of creep data for bio-based composites. Finally, they looked at the mechanical properties of bio-based composites as well as the ramifications for the environment. It demonstrates how these components can be used to create an environmentally friendly alternative to traditional combinations (Miller, 2018).

As illustrated in the diagram, lignocellulosic fibers, often known as cellulose-based fibers, can be classified into wood and non-food or plant fibers. By far the most frequent are wood fibers. Plant fibers, such as cellulose, hemicellulose, lignin, and pectin, account for a considerable portion of the market. Several fiber characteristics can be approximated using the relative content of these constituents (Righetti et al., 2017).

Non-food lignocellulose fibers included seed fibers, bast or stem fibers, leaf fibers, stalk fibers and fruit fibers. Bast is the source of most industrial fibers. This fiber come from the phloem that surrounds the stem and it only exist on plants that reach a certain pitch, allowing high-strength fibres to maintain their stability. Leaf fibers are also commonly used as raw materials. However, they have a lesser rigidity (Lobo et al., 2021).

Thermosetting and thermoplastic resin composites are the two types of resin composites. Natural lignocellulosic fibers are included in this category. Flax, hemp, henequen, sisal, coconut, jute straw, palm, bamboo, rice husk, wheat, barley, oats, rye, sugar, reeds, kenaf, ramie, oil palm, coir, banana fiber, pineapple leaf, papyrus, and wood have all been used as reinforcement. (Alavudeen et al., 2015).

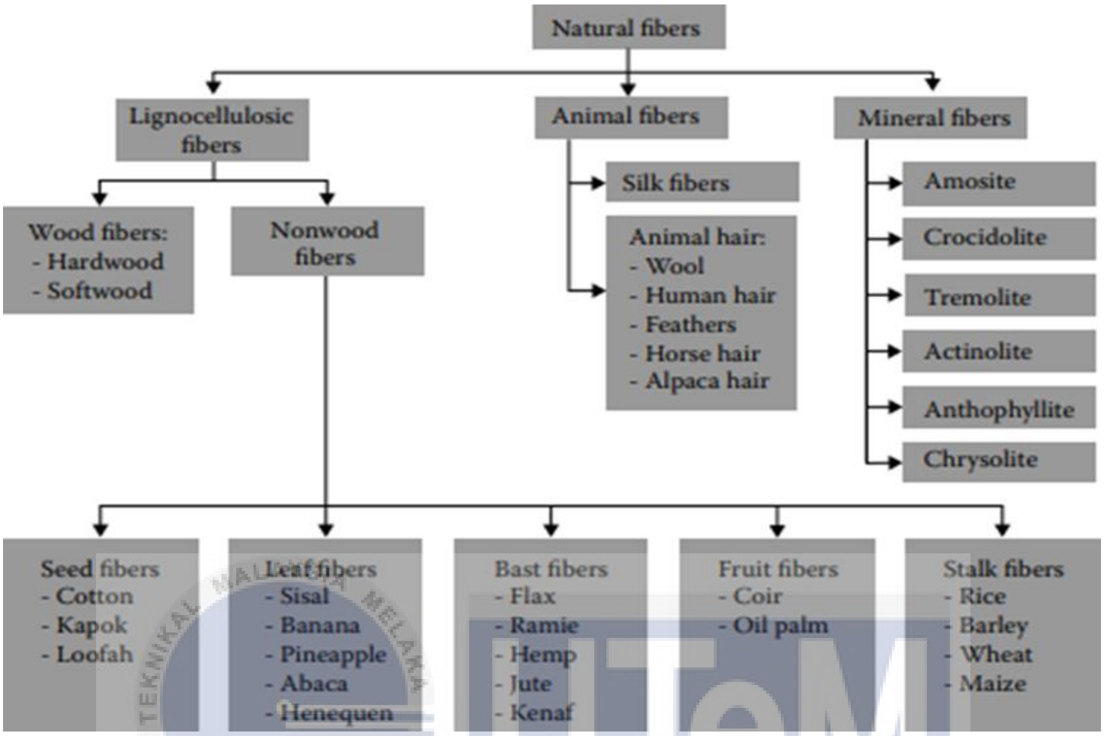


Figure 2.2 Natural fiber classification (Campilho, 2016)

Figure 2.2 which are lignocellulosic materials, animals, or minerals (Campilho, 2016). Furthermore, natural fiber degradability will substantially promote natural fiber composites recyclability properties. As a result, end-of-life products built of composites could be improved in terms of environmental efficiency. As a result, while assessing the added benefits of natural fiber composites for future industries, unique features of natural fiber composites should be considered (Bharath and Basavarajappa, 2016).

Mineral fibers are natural or transformed fibers made from minerals. Mineral composites are natural composites made from minerals. Asbestos is a naturally occurring substance that appears as bundles of fiber. There are six categories for mineral fibers, including amosite, crocidolite, tremolite, actinolite, anthophyllite, and asbestos chrysolite. Proteins are found in animal fibers such as silk, wool, human hair, and feathers. Wool is crimped, elastic, and grows in staples, which sets it apart from other fibers. Wool from sheep and goats, alpaca, and horsehair are examples of animal fibers in general. The type of fiber is silk. They're made of natural proteins and can be woven into fabrics. Natural fibers are durable. Sources are categorized. There are some sources of animals and plant that can composite without any natural wastage.

2.5 Work Material

"Work material" term refers to the materials, instruments, machines, parts, installations, facilities, supplies, and resources required for the execution of the work that are not to be incorporated into or consumed during the execution of the work in the engineering manufacture. This experiment will use a variety of materials.

2.5.1 Polyester Resin

Polyester resin used to create resin sheets was based on a low-viscosity orthophthalic polyester resin (UP-973 ST V, Reefiran Polimer Khodrang, Iran). Due to its low viscosity and non-thixotropic makeup, it is particularly well suited for hand lay-up (HLU) and resin transfer moulding (RTM). Sheets of different thicknesses were moulded using the hand lay-up (HLU) method. By employing a Santam universal tensometer at 25–20C, tensile measurements for the polymer resin were acquired (15T). According to ASTM D 3039, tests were performed using a minimum of five specimens (dumb-bell specimens) and a cross-head rate of 2 mm per minute. Utilizing rectangular specimens with dimensions of 150 mm in length, 25 mm in breadth, and 6 mm in thickness, single edge-notch tensile (SENT) geometry was used to test the matrix's fracture characteristics. (Davallo et al., 2010).

Polyester, monomer, and inhibitor are the three key elements that are often present in commercial polyester resins. The most widely used monomer in industry is styrene, which was the only one utilised in this investigation. In order to give storage life for the product before it is catalysed and working life for the liquid resin once it is catalysed, an inhibitor is required in a polyester-styrene resin. The resins employed in this work contained hydroquinone for this reason. The resins utilised in this work contained quinone for this reason. A commercial polyester resin typically contains 50 to 85% polyester. These polyesters are made by esterifying a glycol with one or more dibasic acids. (Davallo et al., 2010; Jacobs & Jones, 1992).

In this research project, polyester resin has been chosen as the matrix material. Aryan Composites Private Limited provided the resin, which has a density of 1.159 g/cm3 and a tensile modulus of 22.9 MPa. The raw material pineapple leaf fibre, which was provided by Sreekruti Agro Power Equipment in Shivamogga, has a density of 1.526 g/cm3 and a tensile modulus of 170 MPa. It was employed as a reinforcing phase in composite materials (Mittal & Chaudhary, 2019).

2.5.2 Pineapple Leaf

Due to the rising expense of petroleum and the growing environmental impact of utilising synthetic fibre reinforced polymer composites, there has been a lot of interest in using natural fibres to create bio-based composites for a variety of purposes during the past few decades. Numerous plant and fruit parts could serve as reliable sources of unprocessed fibre for use in industry. In spite of this, a lot of plants and fruits are wasted since people are ignorant of how to use them economically when there isn't a good crop. (Senthilkumar et al., 2019a) .

Many authors have recently investigated the hybridization of natural fiber-based composites and achieved high mechanical performances. Pineapple leaf fiber (PALF) is an underutilised material that can be commercialised after being projected as a reinforced material with several types of polymers. PALFs were harvested and retted in Indonesia and

Malaysia for use as filler in hybrid composites manufacturing in this study (Agrebi et al., 2020).

Due to its many beneficial qualities, including their low density and cost, biodegradability, high specific strength, and renewability, natural fibres (NFs) have been employed for reinforcement in a variety of polymer matrixes. Researchers are motivated to use natural fibres (NFs) as reinforcement in the production of composite materials in order to produce composites that are equivalent to or even superior to composites made with synthetic fibres like glass, carbon, and aramid. Other plants, such as those produced for their fruits like the banana, coconut, and pineapple, have supplementary fibre value in addition to those mentioned above. However, these fibres are rarely utilised since they are thrown away as agricultural waste. (Siakeng et al., 2018) .

It has been emphasised the need of employing agricultural waste to grow the efficient deployment of natural resources like pineapple leaf, wheat and banana straw, betel nutshell, and so forth. All around the world, pineapples (Ananas comosus) are picked for their fruit. Due of its looming financial situation, its leaves are the most important components of the plant that were either unused or occasionally rotting by burning. Modern technologists are now concentrating their efforts on creating eco-friendly and biodegradable items rather than artificial materials as a result of this. Traditional methods of rotting and burning the leaves in place did not improve the fertility of the soil, and burning these good agricultural wastes pollutes the environment. (Rahman et al., 2019).

In addition, burning these wastes results in air pollution, which is bad for the environment. In order to replace non-biodegradable polymer, turn waste fibres into useful industrial and commercial products, and replace the use of conventional synthetic fibre that is not only expensive to process but also unfriendly to the environment, engineering research into natural fiber-reinforced biopolymeric composites, such as pineapple leaf fibre (PALF)-reinforced polylactic acid (PLA) composites, is crucial.

A lot of agriculture waste is produced each year in a tropical country like Malaysia where agriculture is active. Thailand produced 1.894 million tonnes of massive agricultural waste in 2009, the Philippines produced 2.198 million tonnes, and Brazil produced only 1.43 million tonnes, as shown in Fig. 2.3.

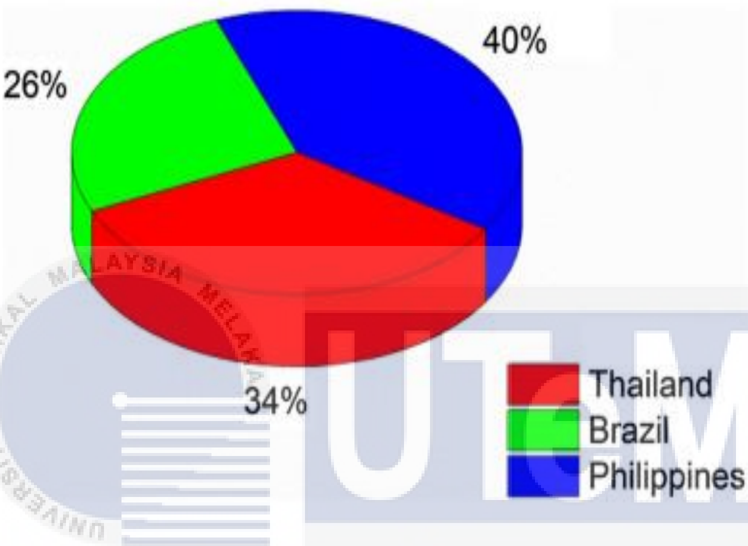


Figure 2.3 agriculture waste (Siregar et al., 2019)

Thailand is one of the world's largest pineapple producers, and as a result, tonnes of pineapple leafs are turned into agricultural waste after harvesting, whereas Malaysia generates approximately 1.2 million tonnes of agricultural residuals annually (Siregar et al., 2019).

In this research, pineapple leaf fibers derived from agriculture are used as reinforcement in epoxy matrices. The purpose of this material was to investigate pineapple leaf fibber's potential as a reinforcement material in epoxy matrix composites using pineapple leaf fiber and epoxy. Figure 2.4 show the pineapple leaf were taken in Malaysia. Figure 2.5 shows the pineapple leaf particle.

Figure 2.4 Raw pineapple leaf

Figure 2.5 Pineapple Leaf Particle

2.5.3 Properties of Pineapple Leaf

Agro-waste fibers, such as coconut coir and pineapple leaf fibers (PALF), are gaining popularity due to their low density and thermal conductivity, which enable them to produce cost-effective and lightweight composite products. PALF is a smooth, glossy fiber with a high cellulosic content (70-82 percent), hemicelluloses (18.8 percent), and lignin (5-12.7 percent) and a softer surface than other NFs. The choice of polymer is determined by the requirements for specific applications and performance (Siakeng et al., 2018) .

PALF is primarily grown in tropical countries, and each plant has 25–30 leafs that can grow to 90–150 cm in length, 2 cm in width, and 5 cm in height. PALF can be extracted using either (I) water retting and scrapping or (ii) microbial retting. The microbial retting process was discovered to be more effective in producing fibers with good appearance, strength, and essential chemical composition. PALF contains 70–82 percent cellulose, 5–12 percent lignin, and 1.1 percent ash. (Senthilkumar et al., 2019a).

Furthermore, a yield of 1.22 tonnes of leaves per hectare has been studied, with a production of 40 leaves per pineapple plant and a mass of 0.065 kg per leaf. Raw leafs contain approximately 85% water, 10% non-fibrous material, and approximately 2.8 percent PALF by weight. PALF has a variety of chemical compositions, including cellulose (67.12–82%), hemicellulose (9.45–18.80%), lignin (4.4–15.4%), pectin (1.2–3%), fat and wax (3.2–4.2%), and ash (0.9–2.7%) (Rahman et al., 2019).

The pineapple leaf When natural fiber is reinforced with a hydrophobic matrix, the hydrophilic properties of cellulose cause a poor interface and low resistance to moisture absorption. Aside from that, previous research has shown that natural fiber reinforced PLA composite has better mechanical properties than natural fibre reinforced propylene or polyethylene. Although natural fibre and PLA matrix have poor interfacial bonding, their mechanical properties can be improved by adding surface treatment or a computerising agent (Siregar et al., 2019).

Pineapple leaf fibre is a natural fiber that has been used in the fabrication of composites. Pineapple leaf fiber (PALF) is one of these and is burned as agricultural waste. PALF comes in white, sleek, and shiny finishes. PALF is made up of 70-82 percent cellulose, 5% lignin, and 1.1% ash. PALF outperforms other fibers due to its high cellulose content. They also have greater mechanical strength and biodegradability than other natural fibers (Hoque & Faruque, 2021).

Demand for cellulose is rising in lockstep with population growth. To meet this demand, synthetic fibers are increasingly being used, posing a significant threat to our environment. Scientists and environmentalists are collaborating to replace synthetic fibers with natural fibers. Among the various types of natural fibers, Pineapple Leaf Fibber (PALF) stands out for its cellulose content, cost effectiveness, eco-friendliness, and fiber strength. In this study, the authors attempted to focus on the extraction process of PALF from leaves, characterization of PALF, and applications of PALF to produce various value-added products (Uddin et al., 2017).

Furthermore, pineapple fibers have a high moisture binding capacity, even greater than cotton. Cotton absorbs only about 7.8 percent of moisture, whereas pineapple absorbs 81.6 percent. It is also stated that the surface of the fibers exhibits characteristics of pineapple leaf fibers as natural fibers (natural fibers), such as smoothness, strength, absorption, and ductility or elasticity(Widowati & Amalia, 2021) .

2.5.4 Application of Pineapple Leaf

The PALF has a cellulose content of 70–82%, a lignin content of 5–12%, and an ash content of 1.1%. Extracted fibres could be utilised to create mats that are woven, knitted, or non-woven. Additionally, PALF is utilised in both medications and animal feed. Arib et al. claim that the PALF is superior to other natural fibres in terms of mechanical characteristics and cellulose concentration. In a different study, PALF reinforcement in PALF/phenolic polymer composites showed a notable propensity to efficiently transmit load from the matrix to the fibre, leading to better mechanical properties. The construction sector, automobile components, machine supports, and component parts all benefit from dynamic qualities (Senthilkumar et al., 2019a).

Regular fiber composite materials have been found in applications other than the locomotive industry, such as doors, window frames, and bicycle frames, as well as the building and assembly industries, aerospace sports, and others. Composites are macro-scale resources made up of two or more naturally diverse components, each with its own boundary.

One or more disjointed stages are implanted in a constant segment to create a composite material. The intermittent stage is typically more difficult than the constant stage and is known as the matrix phase, whereas the constant stage is known as the matrix phase (Gaba et al., 2021).

According to (S. Mishra et al.,) the PALF has a high modulus and thus has a high potential for use in the rubber industry (34.5-82.5 GPa). The tensile and tear strength of NBR composite were increased to 10 MPa and 100kN/mm, respectively, by the loading of 30phr PALF, according to U. Wisittanawat et al. According to (N. Kengkhekit et al.), the PALF can be effectively used in a polypropylene matrix. Despite having many advantageous properties, the PALF has a lower impact toughness than the COIR.

The size of these structured material markets, which range from simple to complex strength applications, is significantly influenced by current and developed composite materials. Military, vehicle, and avionics organisations used these transported materials. Their innovations are particularly appealing because they outperform most existing materials, such as metal, in terms of express quality, lightweight, low thickness, improved utilisation, and temperature capacity. Being biodegradable and green is an added benefit, as is its promise to nature (B a et al., 2020a) .

Last but not least, natural fibre composites have drawn a lot of interest and are viewed as a superior alternative to artificial and synthetic fibre composites in civil, automotive, marine, and aerospace applications due to their common characteristics like low cost, low density, pollution free, and adequate mechanical properties despite the obstacle of poor interfacial layer bonding with polymeric materials due to their hydrophilic character making them incompatible. Based on the composites' viscoelastic behaviour, it has been determined that interfacial bonding is increased and that surface modification of natural organic fibres is necessary to boost compatibility. (Sathees Kumar et al., 2021).

2.5.5 Pineapple Leaf Fiber

The classification of pineapple leaf fiber (PALF) is based on where it is found in plants and how it is extracted. The texture of PALF is thought to be the best of any vegetable fiber. It contributes to climate restoration and soil quality by preventing soil erosion. This chapter discusses pineapple cultivation practises, plant anatomy, varieties, diseases, nutritional needs, utility, and global production. This chapter also looks at plant distribution, varieties, fruit and fiber yield potential, and other factors. Post-harvest operations, decorating techniques, fiber retting, finishing, chemical composition, and physicochemical properties are all covered. It also discusses the benefits of plants to farmers, consumers, and the environment (Pandit et al., 2020) .

Figure 2.6 Pineapple leaf sample fiber (Pandit et al., 2020).

Pineapple leaf fibre (PALF) has the potential for polymer reinforcement, is widely accessible, reasonably priced, low density, and is nonabrasive. It can also be filled to a high fill level, consumes little energy, and has high specific characteristics. A novel field of research in polymer science and technology is the use of pineapple leaf fibre (PALF) as reinforcements in thermoplastic and thermosetting resins in micro and nano form for the creation of inexpensive and lightweight composites. In this study, we examine the industrial uses of PALF, emphasising the manufacturing of specialised papers, chemical feedstocks (e.g., bromelin enzyme), and fabrics. (Leao et al., 2010).

Pineapple Leaf Fibre (PALF), which is used as a reinforcement fiber in most plastic matrix, has proven to be important because it is inexpensive, has superior properties when compared to other natural fibers, and promotes agriculture-13-based economies. PALF is a multicellular and lignocellulose material derived from the leaves of the Bromeliaceous plant Ananas cosmos through retting (separation of fabric bundles from the cortex). PALF has a ribbon-like structure and is held together by lignin and pentosan-like materials, which increase the strength of the fibber (George et al., 2000). According to Figure 2.7, the PALF, like other vegetable fibers, is a multicellular fibre.

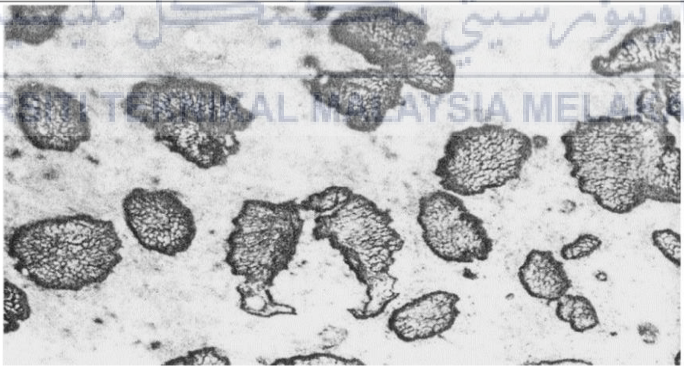


Figure 2.7 Optical Micrograph of Cross Section of PALF (× 160 magnification) (Mukherjee et al., 1986)

2.6 Processing Technique

Hand laying, vacuum infusion, resin transfer moulding, and compression moulding are just a few of the traditional composite component manufacturing methods. This technique has been refined and proven to yield high-quality composites. The processing method was developed to accommodate product-specific designs, with the material, design, and application determining the method used for a specific product. As a result, in this case study, the hand lay-up method was used to create the composite.

2.6.1 Hand Lay-up Method

The simplest and earliest open moulding technique for creating composites is hand lay-up. Prior to applying the resin matrix with a brush to the reinforcing material, dry fibres in the form of woven, knitted, stitched, or bond fabrics are manually put into the mould. To improve contact between the reinforcement and the matrix, enable consistent resin dispersion, and reach the appropriate thickness, the wet composite is subsequently rolled with hand rollers. The laminates are then given time to cure under typical atmospheric conditions. Four steps make up this process: setting up the mould, applying the gel coating, laying it out, and curing it. A fiber-reinforced resin composite can be hardened using the non-heated process of curing. To produce a high-quality product surface, a coloured gel coat is first applied to the mould surface. The laminate is frequently made with a lot of voids. Hand lay-up resins could be more toxic than substances with larger molecular weights because of their smaller molecular weights. The resins are more likely to penetrate garments since they have a lower viscosity. For resins to be handled by hand, their viscosity must be low.In this work, composite specimens were created using the hand lay-up technique and split type moulds. Hand lay-up is a moulding technique in which fibre reinforcements are manually placed and then wet with resin. This method's manual design allows for the consideration of virtually any reinforcing material, chopped strand, or pad. Similarly, the resin and catalyst blend can be altered to provide optimal processing conditions. (B a et al., 2020a)

Hand lay-up composites were created using the compression moulding process. In this work, split type moulds made of EN90 steel were used to fabricate the composites, which consisted of three parts: the flat surface bottom plate, the middle plate with a rectangular cavity, and the top mould. Molds were cleaned and waxed before being polished. Washed and dried PALF of 3 mm length were randomly arranged in the mould at different loading percentages of 25, 35, and 45 percent by weight. The resin (containing 1.5 wt% initiator) was poured onto the fibres, and the mould was closed before compression at 17 MPa. The setup was left undisturbed at room temperature for 24 hours to allow the resin to cure (Senthilkumar et al., 2019b).

The composite specimen in this investigation was made using the hand lay-up method. Another name for the hand lay-up technique is the wet lay-up technique. These composite materials are made in a closed mould that is 360 x 280 x 5 mm in size. UP and PALF were blended collectively when creating the composite specimen. The entire mixture needs to be agitated carefully in order to prevent bubbles from forming. After that, the mixture was put into the mould. The fibre length and content are broken down in Table 2.1. The composite was allowed to cure at ambient temperature. Each composite plate was sliced into specimen size in accordance with ASTM D3039. (Siregar et al., 2014).

Table 2.1 composition of fibre length and fibre content (Siregar et al., 2014).

PALF/UP	Fibre length (mm)	PALF content (vol%)	UP (vol%)
PALF/UP (5% vol. of fibre)	< 0.5 0.5-1 1-2	5 5 5	95 95 95
PALF/UP (1-2 mm length of fibre)	Pure UP 1-2 1-2 1-2	0 5 10 15	100 95 90 85

2.7 Cutting Process Machine

The cnc-router machine will be used to cut fabricated materials into test specimens for the project. Furthermore, the specimens are cut in accordance with a specific size range, parameters, and tool eye speed. As a result, researchers who have used this machine to cut specimens will be included in this literature review.

2.7.1 CNC router machine process

This CNC router machine may be used to cut, engrave, and mark things made of wood, acrylic, and PCB. Using serial communication, design images created on a PC are transmitted to the microcontroller, where CNC operations are subsequently carried out on the object in accordance with point coordinates. According to the design drawings, drill spindles will automatically pattern-create things. After testing, the CNC machine may be used to create 2D or 3D objects with 98.5% carving precision and 100% depth accuracy by cutting, engraving, and marking wood, acrylic, and PCB. The largest thing that can be worked on by this machine is 20 × 20 cm (Ginting et al., 2017).

It is interesting to design and build a router machine for woodworking that is run by CNC software. By creating this machine, it will be possible to make the woodworkers more accurate and efficient for large-scale production. by cutting, engraving, and marking wood, acrylic, and PCB. The largest thing that can be worked on by this machine is 20 × 20 cm. The design and fabrication phases of the development of router machines based on CNC programmes for engraving machines were separated. The router machine that is made will be used for wood engraving with various types of wood with the driver of a stepper motor that moves on 3 axes. This is intended so that the wood craft results can have a good precision and accuracy. The G-code CNC software Mach 3 is used, as in the following Figure 2.8 (Bangse et al., 2020)

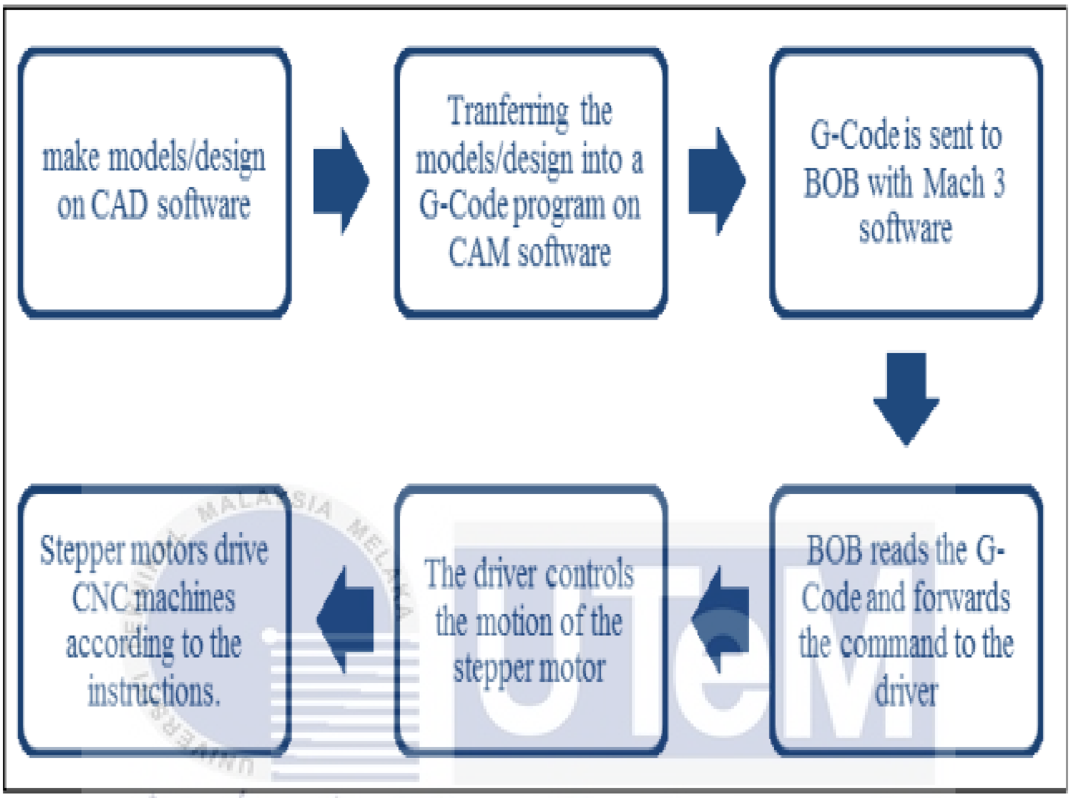


Figure 2.8 Workflow of G-code (Bangse et al., 2020)

Prior to tensile testing, the composite samples were cut to a rectangular shape with dimensions of 120 *20 *3mm using a cnc- router machine. Mechanical characterization was carried out in accordance with the ASTM D 3039 (2014) standard, with the crosshead speed set to 5mm/min and the gauge length set to 50mm. Tensile tests were carried out with a maximum load cell of 5 kN. The impact strength of DPF/epoxy composites was measured using a CEAST 9050 impact testing machine under various loading conditions (Instron, Norwood, USA). Using a cnc- router machine, the composite samples were cut into rectangular shapes with dimensions of 70 *15* 3mm (Saba et al., 2019).

Lastly for flexural test the ASTM D790 standard was used to prepare five samples of each epoxy composite for testing. The cnc-router machine was used to cut the samples, and the milling machine was used to finish them. The samples had dimensions of 8 mm x 12.7 mm x 101 mm(Jaafar et al., 2018) .

2.8 Machine Testing for Specimen

Operational testing ensures that the product, system, service, and process meet operational requirements. Efficiency, dependability, durability, maintainability, connection, interoperability, backup, and recovery are all operational factors. It is a method of determining non-functional acceptability. Operational testing, as well as operational support and components, are required during operational setups. The elements on which operational 35 research is founded are critical (Vasu et al., 2017). Figure 2.8depicts the test method classification.

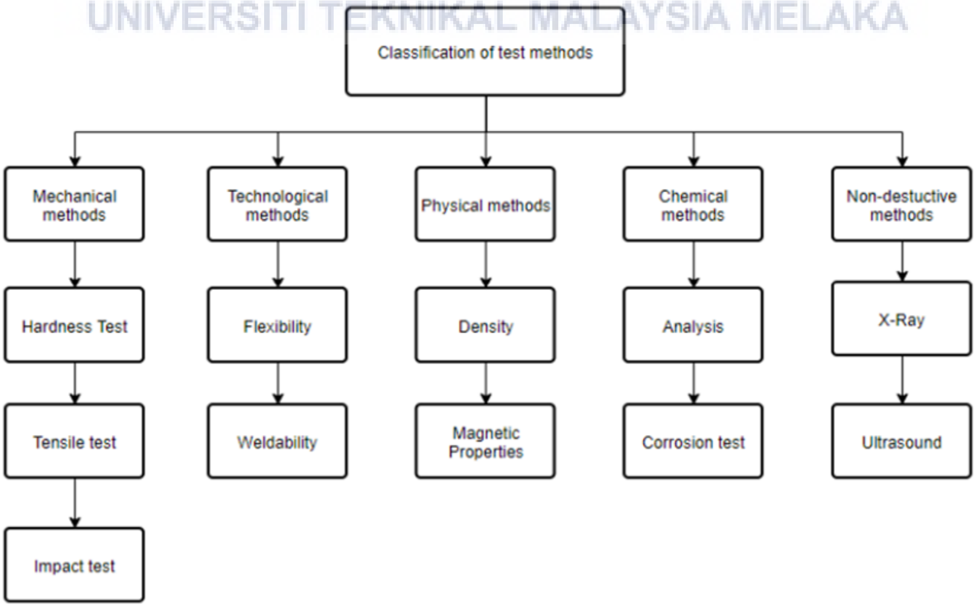


Figure 2.9 Classification of test method (Vasu et al., 2017)

2.8.1 Impact Testing

The charpy v-notch test, also known as the charpy impact test, is a higher strain-rate standardised test that determines how much energy a material absorbs. The notch toughness of the material is used to calculate the absorbed energy. The Charpy impact test has been used in numerous studies for composite testing.

ASTM A370 was used to calculate the specimen sizes. Metal testing is covered by the ASTM A370 standard. The Charpy impact test was carried out on a Reihle impact test apparatus. The lightest impact weight was selected to produce the best resolution. Due to the lack of a standard for Charpy impact testing on composites, the standard was altered to cover composite materials. Following the standard 36 standards, specimens had to be 55 mm long and 10 mm thick, with the thickness variable depending on how the panel was laid out. ASTM A370 was used to calculate the specimen sizes. Metal testing is covered by the ASTM A370 standard. The Charpy impact test was carried out on a Reihle impact test apparatus. The lightest impact weight was selected to produce the best resolution. Due to the lack of a standard for Charpy impact testing on composites, the standard was altered to cover composite materials. According to the standard 36 criteria, specimens were to be 55 mm long and 10 mm thick, with the thickness variable depending on how the panel was laid out (Flynn et al., 2016) .

According to research, the samples were prepared in accordance with ASTM A370 requirements for the impact test (Bhoopathi et al., 2017). There were developed separate hybrid composite laminate test samples reinforced with glass, hemp, and banana fibres. A computer-controlled impact energy testing unit was used to determine the maximum impact energy of each hybrid composite laminate test sample. For results analysis, the impact energy values of each sample of these composites are recorded. Figure 2.9 depicts a standard size impact test specimen.

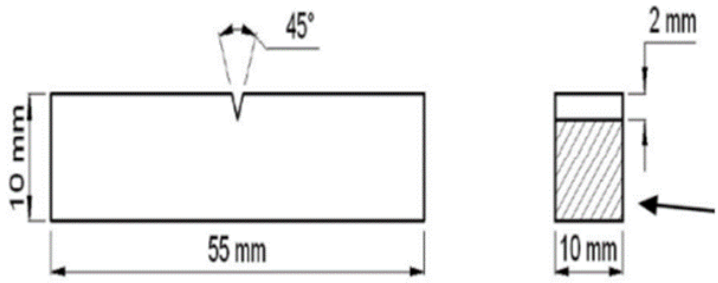


Figure 2.10 ASTM A370 Size Specimen

The charpy test, according to Hemanth et al. (2017), is used to determine the impact energy of composites to assess the specimen's shock resistance. In joules, the amount of energy absorbed by the specimen prior to failure was measured. The amount of energy acquired in joules indicates the material's resistance to shock loads. Specimens produced in accordance with ASTM A370 standards (55 x 10 x 10 mm) were used for this procedure. The brittle nature of the composites resulted in lower impact test results for the pineapple leaf fibre reinforced composites.

The impact strength of developed composites was also reduced in the natural soil environment. Water molecule entrapment at the fiber-matrix interfacial region causes this type of behaviour, resulting in easy and smooth fibre pull-out from the viscoelastic medium. The pure Coir-Epoxy composite exhibits a higher rate of impact strength reduction after 60 days of burial than the PALF-Epoxy composite, regardless of the chemical composition of the PALF and COIR fibres. The total loss (percentage) in impact strength of the Coir-Epoxy composite, on the other hand, was 15.9% less than that of the PALF-Epoxy composite (Mittal & Chaudhary, 2019).

2.8.2 Flexural Test

Because the physical properties of different materials vary, it is sometimes necessary to test the material at a temperature similar to the final use environment. Flexural tests for rigid and semi-rigid materials, resins, and laminated fibre composite materials are commonly used to assess the force required to bend a beam under three-point loading conditions. The most common flexural tests for polymer composites and large fiber-reinforced plates are three-point flexural tests in accordance with ASTM D 790 to ensure suitability under various conditions to obtain a better picture of its properties and to ensure it is suitable for the intended application. Flexural testing also provides a semi-quantitative estimate of a 39 composite's fibre interfacial strength. The testing of flexural properties yields editable and raw data on flexural stress and strain at yield, flexural stress and strain at break, flexural stress deflection, flexural modulus, and stress/strain curves (Saba et al., 2019).

The specimen was made in the ASTM D790-07 size for flexural testing, which is 10mm x 4mm x 80mm. A three-point flexural approach was used in the current studies. The researchers used a crosshead speed of 2 mm/min. The drawing and dimensions of bending equipment used in flexural testing are shown in the figure. The image depicts the design and dimensions of bending equipment used in flexural testing (Yousif et al., 2012).

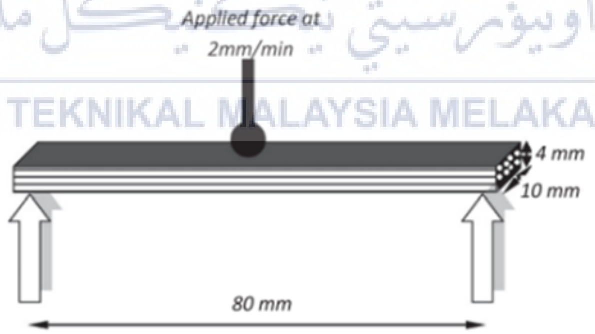


Figure 2.11 The design and dimensions of bending equipment

Figure 2.11 depicts the design and dimensions of bending equipment used in flexural testing. Other researchers have used ramie fibre in conjunction with glass reinforced with epoxy resin. To determine mechanical properties, they used tensile testing, flexural testing, and impact testing. They followed the ASTM D790-70 dimension of flexural test standard specimen during flexural testing. The specimen dimensions (80mm x 10mm x 4mm) are a composite. There are three material 40 ratio mixtures with epoxy that are RFREC (Ramie fibre reinforced epoxy composite), GFREC (Glass fibre reinforced epoxy composite), and HFREC (Hybrid fibre reinforced epoxy composite) in 20% and 30% material mixtures. Flexural testing results indicate that 30% hybridization of FRP has the highest flexural strength rating of HFREC with a ramie fibre to glass fibre ratio of 1:2. Flexural strength improves by 6% when compared to GFREC and by 23% when compared to RFREC. Glass fibre reinforced composites have higher flexural strength than ramie fibre reinforced composites because glass fibre can withstand greater bending stresses than ramie fibres. HFREC has a higher flexural strength than glass fibres due to its stiffness. Researchers proposed that composite be used for door panels, room partitions, and wall cladding because hybridization reduced its cost and made it an eco-friendly composite(Giridharan, 2019) .

Hamdy et al. (2018) use date palm fibres to create reinforced epoxy composites. The mechanical properties of composites are of interest to researchers. The process includes flexural testing, thermogravimetric analysis, and dynamic mechanical analysis. The crosshead speed on the upper and lower surfaces was set to 2 mm/min, and the specimen size was tested in accordance with the ASTM D790 standard. Date palm fibres are evaluated in three different ratios: 40 percent, 50 percent, and 60 percent. They focus on two aspects to evaluate the effect of date palm fibres on the flexural strength and modulus of epoxy composites. Flexural strength and modulus of epoxy composites improve to 32.64 MPa and 3.28 GPa, respectively, at 50% date palm fibre loading, compared to 40% and 60%. In comparison to the other composites, 50% date palm fibre loading shows the greatest improvement. According to the researcher, this effort may be able to reduce massive date palm wastes while also attempting to reduce the use of existing synthetic fibres in the polymer composite sector for advanced engineering applications such as automotive, paper making, and outdoor applications.

Tensile and flexural testing are effective methods for determining composite strength. They are more of an experiment with eco materials that are Napier fibre reinforced composites, according to the researchers. A nearby plantation provided the Napier grass. Researchers conduct flexural testing to determine the composite's maximum flexural characteristics. The test was performed by ASTM D7264-14, which has dimensions of 125mm x 13mm x 3mm. The crosshead travels at a 2.5 mm/min speed and has a span-to-depth ratio of 16:1. The epoxy resin was mixed in three different ratios with increasing amounts of Napier filler (3, 5, and 10% wt). The highest flexural strength and modulus were found in 5 percent Napier fibre reinforced nanomodified epoxy composites. (Ramli et al. (2019).

According to Mehndiratta et al. (2017), Flexural testing can determine the strength of a composite. A laminated specimen with dimensions of 80mm x 10mm x 4mm was created by a researcher by the ASTM D790-70 standard. The substance used to make laminate is carbon and glass-reinforced polymer. Flexural testing investigates the relationship between the test span length and two different materials, carbon, and glass. The results show that the flexural strength of prepreg-layered specimens increases with test span length. Flexural modulus increases with span length up to a point and then steadily decreases in carbon and glass materials.

2.8.3 Tensile Testing

The tensile testing apparatus described in this article was designed to investigate the mechanical properties of another material, but it can be applied to any comparable specimen.

Many researchers studied the mechanical properties of natural fibre composites to determine their tensile strength, modulus strength, hardness, and abrasion resistance.

The tensile properties of the composites were determined at room temperature using a 25 kN Universal Testing Machine (Instron 8872 model). The crosshead speed was set to 2 mmmin1 during the tensile test, as recommended by ASTM D3039. An extensometer was used to measure the tensile strain of the composite materials throughout the tensile test. The three-point flexural test was carried out at room temperature according to ASTM D790 on the same Instron machine used to investigate the flexural strength and modulus of kenaf fibre and PALF composites. A cross-head speed of 2 mmmin1 and a span-to-depth ratio of 16:1 were maintained throughout the flexural test. The energy-absorbing capacity of kenaf fiber- and PALF-reinforced composites was measured in flatwise and edgewise impacted directions using the Instron CEAST 9250 Drop Tower Impact by ASTM D6110 (Feng et al., 2020).

We can conclude that hybrid composites have a higher tensile strength reduction than pure PALF-Epoxy composites. This negative effect of hybridisation in the natural soil environment is caused by water molecule penetration at the interface between the fibre matrix and the fibre-fibre, which results in easy fibre pull-out under mechanical loading conditions. The hybrid composite (P60-C40) loses 70% of its tensile strength in natural soil. This was caused by microorganisms and lignocellulosic fibre hydrolysis. It can be seen that the NaOH-treated Coir-Epoxy composite loses tensile strength faster than the untreated one (Mittal & Chaudhary, 2019).

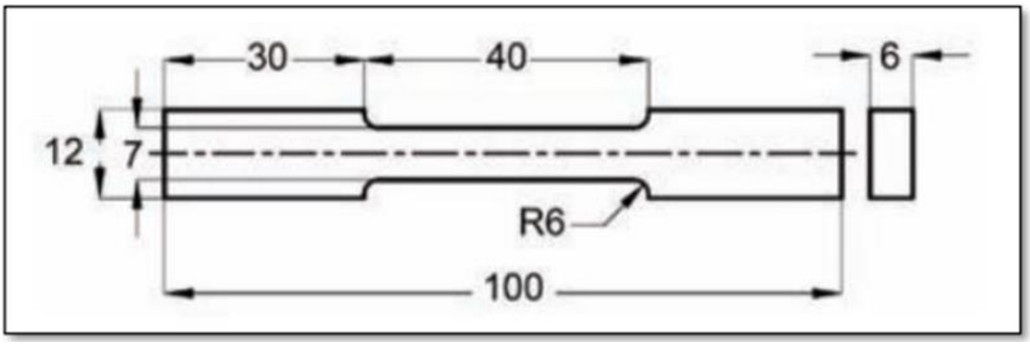


Figure 2.12 Parameter size of the specimen (Subramaniam et al. 2018)

Subramaniam et al. (2018) are working on the fabrication and assessment of the mechanical properties of hybrid aluminium matrix composites. Boron carbide and fly ash particles from coconut shells were used to fortify the aluminium 7075 alloys. Mechanical properties such as tensile strength and impact strength are discussed in this article. The addition of 9wt increased the composites' tensile strength by 66%. Researchers create tensile test specimens with standard dimensions of 6 mm thickness, 12 mm width, 40 mm gauge length, and 30 mm gripping surface length. Tensile strength was determined using automated standard testing equipment. Figure 2.12 depicts the specimen's parameter size prior to tensile testing. Prepared composites were subjected to tensile, compression, and hardness tests. For each test and specimen type, five experiments were conducted. Tensile tests were performed using an ASTM D 638–01 UTM with a total capacity of 45 KN. Tensile testing (also known as tension testing) is a material science and engineering test that subjects a model to continuous stress before failure(B a et al., 2020b).

Tensile testing The composite laminates are cut into rectangular strips according to ASTM D638-3 for the tensile test, with specimen dimensions of 160 mm in length and 14 mm in width. 43 The tensile test is performed on an Instron 4201 universal testing machine (UTM) with a 50 KN load cell. A strain gauge is placed longitudinally on each specimen during testing. At 0.3 percent strain, the strain and Young's modulus (Eact) were measured using a digital strainmeter. The gauge length and strain rate are set to 60 mm and 1 mm/min, respectively, during the tensile test. The apparent tensile modulus is calculated using the stress-strain curve (S. Kumar & Saha, 2022).

2.8.4 Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) is a statistical analysis tool that divides observed aggregate variability within a data set into two parts: systematic factors and random factors. Random elements have no statistical influence on the given data set, whereas systematic factors do. ANOVA is a statistical technique used to determine whether the means of two or more groups differ significantly from one another. ANOVA compares the means of different samples to determine the impact of one or more factors.

Because Test F > F = 1/4.5 percent and P (percentage of contribution) > Error associated, the factors (V and f) have statistical and physical significance. It is worth noting that the error associated with the table ANOVA for the Ra is about 1.7 percent. Figure 2.13 also shows that the feed rate factor (54:9 percent) and the cutting velocity factor (42:8 percent) have statistical and physical significance on the surface roughness (Ra) obtained for ATLAC 382-05 composite material, particularly the feed rate factor. Because Test F > F a 1/4.5 percent and P (percentage of contribution) > Error associated, the factors (V and f) have statistical and physical significance. It is worth noting that the error associated with the table ANOVA for the Ra is about 2.3 percent (Davim et al., 2004).

Table ANOVA for the surface roughness (R_a) for both GFRP composite materials

Source of variance	SDQ	Df	Variance	Test *F*	$F\alpha = 5\%$	*P* (%)
Viapal VUP 9731						
V (m/min)	2.21E−01	2	1.11E−01	95.32	6.94	39.3
f (mm/rev)	3.31E−01	2	1.66E−01	142.75	6.94	59.0
Error	4.64E−03	4	1.16E−03	–	–	1.7
Total	5.57E−01	8	–	–	–	100.0
ATLAC 382-05						
V (m/min)	1.30E−01	2	6.52E−02	75.77	6.94	42.8
f (mm/rev)	1.67E−01	2	8.33E−02	96.79	6.94	54.9
Error	3.44E−03	4	8.61E−04	–	–	2.3
Total	3.01E−01	8	–	–	–	100.0

SDQ—sum of squares, Df—degrees of freedom, *P*—percentage of contribution.

Figure 2.13 anova table (Davim et al., 2004).

This chapter contains detailed information on specific procedures or techniques used to identify, select the method process, and analyze data on this topic. The methodology section in this chapter allows the reader to critically figure out the overall process and rehabilitee. The process flow is being used by this researcher to meet the current work objective. This research will be conducted in three stages. The first stage is to create the experiment material by hand mixing it. The second stage involves cutting the material into experiment specimens with a bandsaw machine and performing three types of testing to determine the material's strength: tensile testing, impact testing, and flexural testing. The final step is to analyze the experiment material. Tensile testing, impact testing, and flexural testing data will be analyzed. We will decide which of the three different testing processes will produce a better result for the quality and mechanical properties of the specimen material. This chapter will provide a general overview of the experiment and technique used to achieve an exact and precise result. This chapter defined the experimental specifics (Haq et al., 2008).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter contains detailed information on specific procedures or techniques used to identify, select the method process, and analyze data on this topic. The methodology section in this chapter allows the reader to critically figure out the overall process and rehabilitee. The process flow is being used by this researcher to meet the current work objective. This research will be conducted in three stages. The first stage is to create the experiment material by hand mixing it. The second stage involves cutting the material into experiment specimens with a CNC router machine and performing three types of testing to determine the material's strength: tensile testing, impact testing, and flexural testing. The final step is to analyze the experiment material. Tensile testing, impact testing, and flexural testing data will be analyzed. We will decide which of the three different testing processes will produce a better result for the quality and mechanical properties of the specimen material. This chapter will provide a general overview of the experiment and technique used to achieve an exact and precise result. This chapter defined the experimental specifics.

3.2 Project Experiment Process

A block diagram for the impact of strength composites analysis on the testing process with three distinct tests. To cut the material in this project, one type of machinery is used. A substance of such importance must be created before conducting the experiment. The fabrication used pineapple leaf powder and epoxy resin with an average size of about 62 m.

After the material had been mixed, it was cured using a hand lay-up and mixed technique. Following the acquisition of the material, the substance will be used to carry out the experiment. To cut the PL composites, a CNC router machine MODELA PRO2 (MDX-540). will be used. The ASTM standard determines the thickness and size of the experimental specimen.

The material will be cut into three sizes based on the type of testing, including impact testing, tensile testing, and flexural testing. The ASTM standard was followed for all cutting specimens. Following that, testing equipment was used to analyse the material's tensile strength, impact energy, and flexural strength. Mechanical testing and the ANOVA method will be used to analyse the strength of the specimen after it has been cut with a CNC router machine.

3.2.1 Process flowchart

The flowchart depicts a procedure in which the steps are performed sequentially. A flow chart is a graph that represents a workflow or process. Flowcharts are also a visual representation of algorithms and job-related procedures. The stages are represented as various boxes on the flow chart, with the boxes connected by arrows. This diagram depicts the model solution to a particular problem. Flowcharts are used to plan and document simple system procedures. A flow chart can help you understand each stage of the process and how it works. Figure 3.1 depicts the process flow from the beginning to the end of the process.

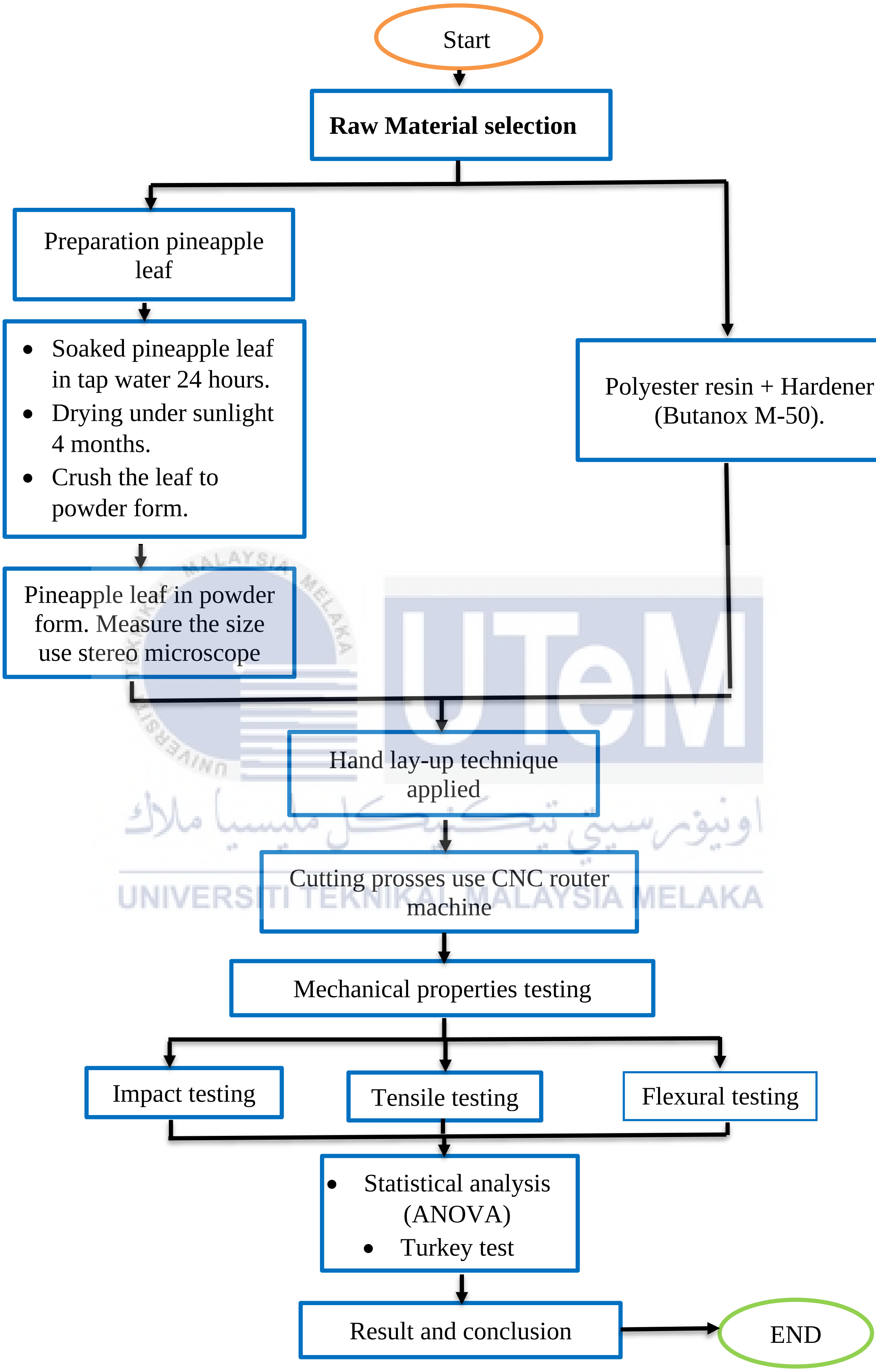


Figure 3.1 Process Flowchart

The flow chart processes depict a procedure that is carried out a workflow. Figure 3.1 above depicts the method in this research from start to finish. To begin, the experimental research process will fabricate the specimen, which is a combination of pineapple leaf and mixed composites, using polyester resin and hardener (Butanox M-50) before cutting to a specific size. The specimen will then be prepared using a crusher machine to make it as powder portion. Hand lay-up process to make the specimen to solid form and dry it for 48 hours. When the materials are perfect, the cutting process can begin.

Furthermore, the cutting process on the specimen involves only one machine, a CNC router machine MODELA PRO2 (MDX-540). The specimen will be cut with a CNC router machine and divided into three sections impact testing, tensile testing, and flexural testing. According to ASTM E23, the specimen size for impact testing is 55mm length x 12.5mm width x 10mm thickness. Then, according to ASTM D3039, the specimen size for tensile testing is 120mm length x 20mm width x 3mm thickness, and the specimen size for flexural testing is 120mm length x 20mm width x 3mm thickness. Every mechanical test has a fixed dimension. Following the testing process on the specimen, collect and analyse data. Use ANOVA to analyzed al the data and make sure there was the data significant or not and use turkey test method to double confirm if the data significant.

3.3 Design of Material Specimen

The sample specimens are designed to collect data and provide results. The specimen dimensions will be divided into three types of testing. Following specimen formation, it will go through an ASTM standard size cutting procedure before being evaluated by impact testing, tensile testing, and flexural testing. These specimens are formed to meet test specifications to identify improved material properties after cutting. Specimens are also available in five ratios: 20 percent PL and 80 percent polyester resin (PLPR20), 40 percent

PL and 60 percent polyester resin (PLPR40), 50 percent PL and 50 percent polyester resin (PLPR50), 60 percent PL and 40 percent polyester resin (PLPR60) and 80 percent PL and 20 percent polyester resin (PLPR80) .Figure 3.2 depicts the size of impact testing specimens, while Figure 3.3 depicts the dimensional size of specimens for flexural test and tensile test.

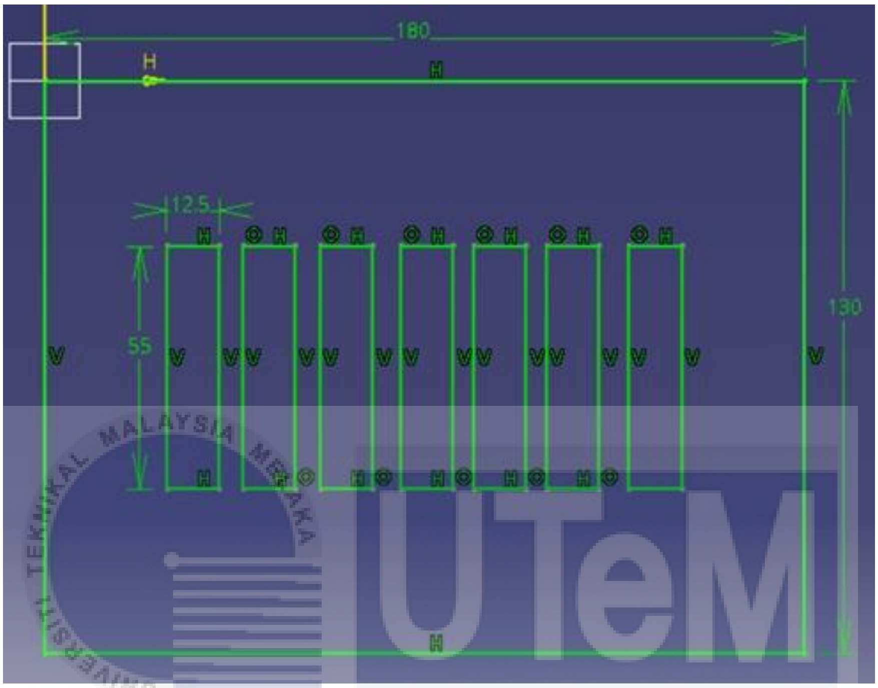


Figure 3.2 Dimension Size of Specimen Impact Testing

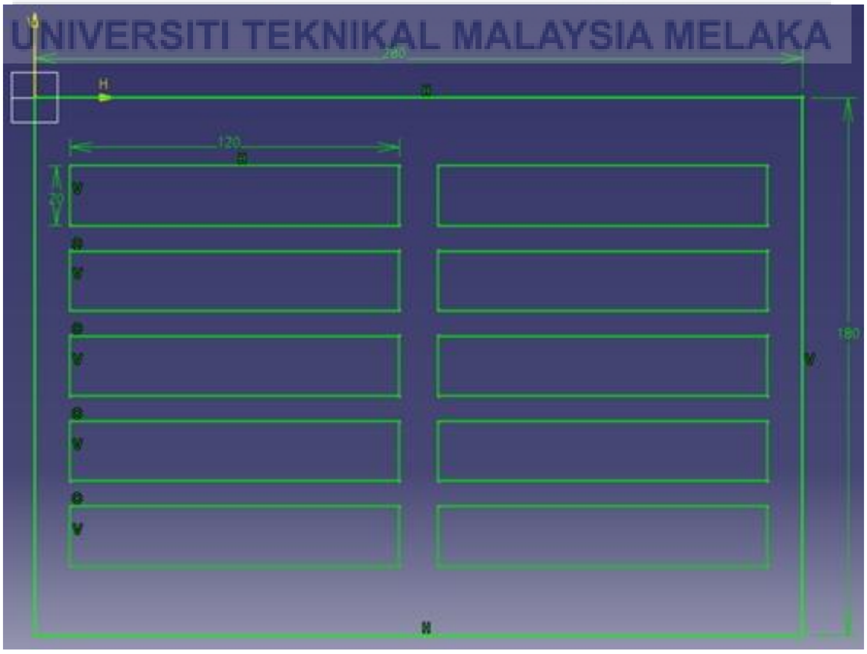


Figure 3.3 Dimension Size of Specimen Flexural and TensileTesting

3.4 Experimental Procedure

This study's experimental approach is a step-by-step technique for each stream. Each procedure or process in this study has its own Standard Operating Procedure (SOP). These processes are critical to ensuring that the processes and operations run smoothly. Each procedure requires the presence of a focus point in order to produce good and precise results. This section will then investigate various phases, including the testing process. Following that, a few significant methods or steps will be discussed in this chapter. The process includes tensile testing, impact testing, and flexural testing.

3.4.1 Fabricate Material

Pineapple leaf were a non-food item found in pineapple. The pineapple leaf is usually discarded and burned after pick the pineapple from the pineapple plant and the leaf also was removed. The leaf was one of the wastes that might harm our environment. The pineapple was pick and purchased by some local fruit dealer from the pineapple farmer. Then, they removed all the leaf from the pineapple. Besides that, the order to produce pineapple leaf powder by extracting the pineapple leaf fibre from the pineapple leaf was soak the leaf in water for 24 hours. The pineapple leaf was taken from a pineapple farm at Pahang. On pineapple leaf powder formation, soaked pineapple leaf are separated to single pieces and sun-dried for several months to eliminate the moisture content. Figure 3.4 shows the pineapple leaf sun–dried. Then, cut the dried pineapple leaf to small pieces using scissors to make it easy to grind as shown in Figure 3.5. Furthermore. Figure 3.6 shows the pineapple leaf grind to become powder using scratcher machine with dry potion and keep it into a dry container to avoid contact from water.

Figure 3.4 Sun- dried pineapple leaf

Figure 3.5 Cut dried pineapple leaf

Figure 3.6 Scratcher machine and pineapple leaf powder

Following the weighing, polyester resin must be applied in a 1:1 ratio. The parameter used to create the composite ratio is shown in Table 3.1. The ratio must per 100 percent so we must made the stability ratio of PL and polyester resin. Polyester resin is made up of two components: resin and hardener. The two ingredients are combined by mixing and stirring until well combined. When the resin and hardener are combined, they go through a complex mixture process that converts the following resin into a solid state with composite. It is critical to precisely measure and carefully mix polyester resin to ensure proper drying.

Table 3.1 Parameter of composite ratio

Abbreviations	Pineapple Leaf Powder (%)	Weight (g)	Polyester resin (%)	Weight (g)
20PL80PR	20	5	80	245
40PL60PR	40	10	60	240
50PL50PR	50	12.5	50	237.5
60PL40PR	60	15	40	235
20PL80PR	80	20	20	230

After that, the material for mold is made from silicone. Two different size of silicon mold was used in this experiment. For tensile and flexural test specimen that dimension of silicon mould is 280mm length × 180mm width and 3mm thickness as in Figure 3.7. Therefore, for impact test specimen the dimension of silicon mold is 180mm length × and 130mm width and 10mm thickness as in Figure 3.8 . The silicone mould used because the silicone does not affect the mixture of our chemical and not sticky.

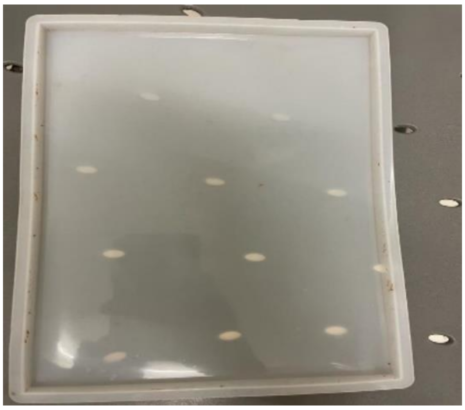


Figure 3.7 Mould tensile and flexural specimen

Figure 3.8 Mould impact test specimen

This hand lay-up method was applly to made the specimen flat and square based on the mold size. Figure 3.9 shows that silicone mould release spray used to make sure the surface of mold clean and avoid the specimen sticky with the mold after dried 2 days in the room temerature.

Figure 3.9 Silicone mould release

Hand lay-up method required the weight of polyester resin and pineapple leaf powder. All the ratio and weight was follow as in table 3.1. Hardener used for this testing was (Butanox M-50). Figure 3.10 show the polyester resin and hardener that was used.

Figure 3.10 Polyester resin and hardener (BUTANOX M-50)

Hand mixing is a moulding technique that involves manually placing PL powder and then moistening it with resin. The two mixtures are thoroughly combined. Before that, the sample is mixed in recycle plastic container to prevent it from sticking as shown in Figure 3.11.

Figure 3.11 Mixed PLPR

After thoroughly mixing, the mixture is poured into a mould as Figure 3.12. Mold preparation must be in a clean state. To prevent the composites from clinging to the mould after removal, the mould was polished with a release agent before being filled with the mixture. Then , the hand lay-up method used to cure the material and make it flatten surface as shown in Figure 3.13. Lastly, use scrapper to equalize all the mixture level in the mould and make it become flat.

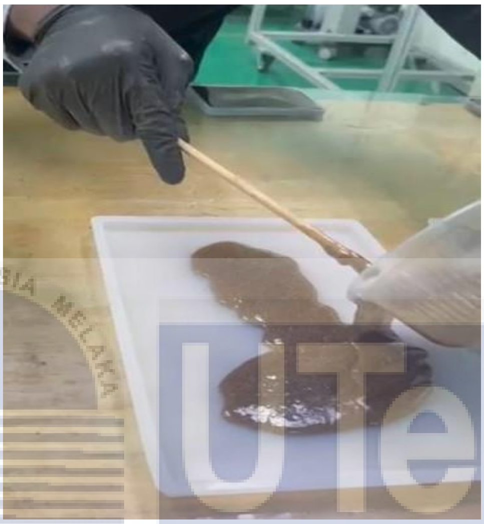


Figure 3.12 Mixture poured in mold

Figure 3.13 Tensile ,flexural and impact test mold

3.4.2 Cutting Process

After the sample had dried and hardened for 48 hours, it was cut with a CNC router machine model MODELA PRO2 (MDX-540). The sample is cut in accordance with the ASTM standard testing method. Before that, a double tape is placed on the sample as a holder for smaple during the cutting process. This double tap is used to ensure that the sample not vibrate during the cutting process . the sample must placed on top of the vice. In the computer control panel , the cordinate must be set zero before start cutting process. The size of cutting tool used is 3mm and the spindle speed is 150 rpm. Figure 3.14 show the cutting style of CNC router machine.

Figure 3.14 Cutting style of CNC router machine.

Place the sample on top of the table to begin. Following that, ensure that the start point and begin the cutting process will . Using the ASTM standard, cut the PLPR sample into specimen size. There are two types of ASTM standards in use. First, the specimen size for impact testing is ASTM E23 (55mm length x 12.5mm width x 10mm thickness). Second, ASTM 3039 specifies the sample size for tensile testing and fleural test (120mm length x 20mm width x 3mm thickness). Figure 3.15 show the sample that cut from the CNC router machine.

Figure 3.15 sample cut using CNC router machine

Total for flexural and tensile we get 14 sample for each ratio after the cutting . While for impact test get 7 pieces of sample for each sample . All samples were cut to size specified. Check that the machine and the cutting tool are in good working order so that the cutting process runs smoothly and produces a good specimen size.

3.4.3 Impact Testing Process

Specimen material will be impact tested with an INSTRON CEAST 9050 machine after the composite specimen has been cut and sized. The impact testing method used was charpy impact testing. The specimen size as specified by the ASTM standard. The ASTM E23 specimen size for impact testing (55mm length x 12.5mm width x 10mm thickness). The total number of specimens to be tested is 25. When the specimen is inserted, the specimen size and drain distance must be determined so that the cut specimen size can be tested on the machine's impact charpy. The specimen retainers are separated by 27.5mm. Specimens with a notch must be in the centre. Figure 3.16 shows the V-notch of the specimen using bandsaw machine.To insert the specimen, the hammer must be lifted and locked. The specimen is then inserted and positioned in the centre. The notch on the specimen is facing the hammer, clockwise. The hammer is then released after the machine's door is closed. This process is repeated until a reading of 25 pieces is obtained. Figure 3.17 shows the type of impact testing machine that are to be used INSTRON CEAST 9050 machine.

Figure 3.16 V-notch of the specimen

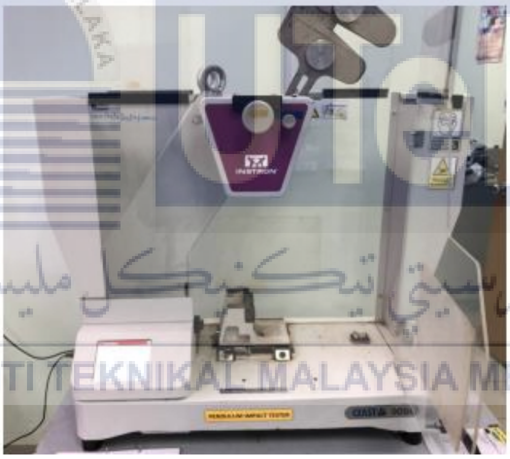


Figure 3.17 Impact testing INSTRON CEAST 9050 machine.

3.4.4 Tensile Testing Process

After determining the size of the specimen, the material will be tensile tested using a universal testing machine. Before beginning the tensile procedure, the test material should be smoothed across its entire surface with sandpaper. This can help to ensure that the material testing process goes as smoothly as possible. The test material must be in good condition before beginning the tensile procedure. The specimen was measure and mark the grib place that was 25mm down and up. Furthermore the specimen size as specified by the ASTM standard. Tensile testing specimen size ASTM 3039 (120mm length x 20mm width x 3mm thickness) at 5mm/min cross-head speed. Figure 3.18 shows the specimen grip.

Figure 3.18 Grip the specimen at specimen grip

The next step is to enter all of the information, which includes 25 test material thicknesses, test lengths, and associated data, into the computer. After the tensile operation is completed, the tensile test results will be displayed on the computer order. So, that the cutting process runs smoothly and produces a good specimen size.

3.4.5 Flexural Testing Process

Flexural specimens are manufactured in accordance with ASTM D790-07 guidelines (120mm length x 20mm width x 3mm thickness) at a cross-head speed of 2mm/min. The 3-point flexural test is the most commonly used flexural test for composite materials. The specimen deflection is calculated using the crosshead location. The test results include flexural strength and displacement. The test specimens are placed in the universal testing machine and subjected to force until they fracture and shatter. Flexural testing will be performed on the specimen material using a universal testing machine. Figure 3.19 show the place of specimen on universl testing machine.

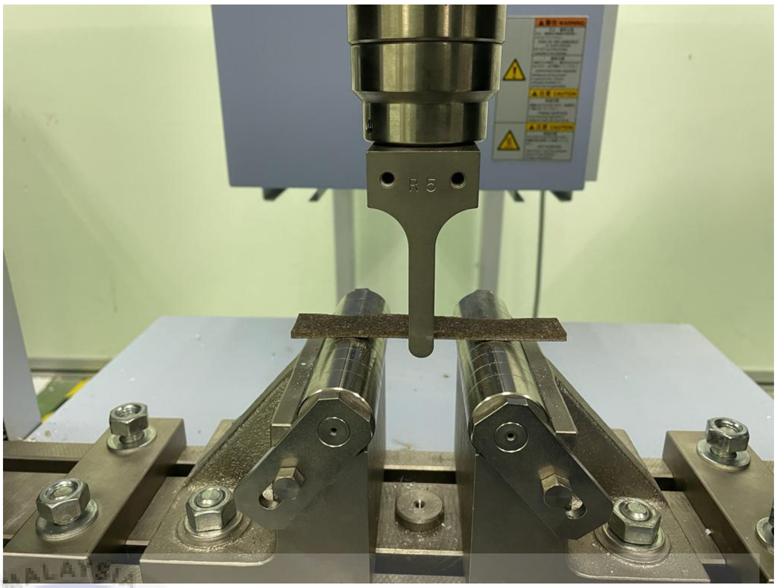


Figure 3.19 Specimen placed on universal testing machine

The test material should be smoothed with a centre line at the specimen surface before beginning the flexural procedure. This can help to ensure that the material testing process goes as smoothly as possible. The test material must be in good condition before beginning the flexural procedure. Then, enter all of the information into the computer, such as the thickness of the specimen, the length of the specimen, and so on. Then, stop the machine after the specimen has broken. Figure 3.20 shows the machine pressure until specimen broke.

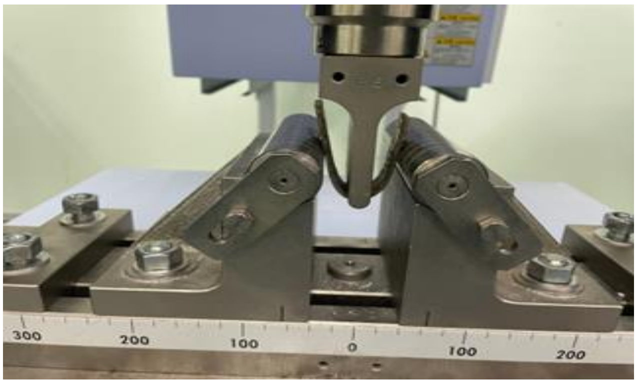


Figure 3.20 pressure of universal machine

3.5 Experiment Setup

This chapter will go over all of the machinings that will be used as well as the equipment configuration for the measure the size of partical of pineapple leaf powder using stereo microscope, cutting and compressing of pineapple leaf composites. The CNC router machine model MODELA PRO2 (MDX-540) will be used to cut the composite specimen. Another method is to use a testing machine type. The experiment setup will display all machines used in the compressing, cutting, and testing processes.

3.5.1 Stereo Microscope

To measure the size of pineapple leaf powder, use a stereo microscope. It is first important to power on the computer and microscope by pressing the switch button. After that, it needs to calibrate using Isolution software on the PC. It may then plainly view the material, as seen in figure 3.21 below. The test can demonstrates the size of pineapple leaf powder was measured using an SMZ754T stereo microscope.Figure 3.22 shows the Stereo microscope SMZ754T.

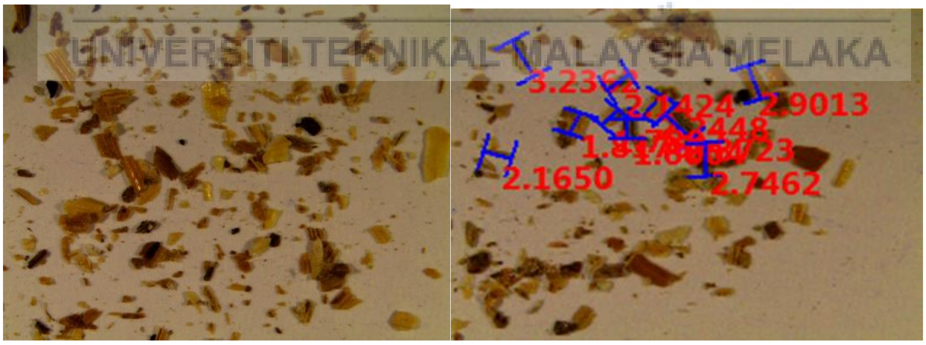


Figure 3.21 Pineapple leaf powder size in stereo microscope

Figure 3.22 Stereo microscope SMZ754T.

3.5.2 CNC Router Machine

This chapter will go over the CNC router machine methodology in detail. The MODELA PRO2 (MDX-540) machine is a specific model. This machine was designed to easily cut a product out of any type of material, including very delicate materialsexcept the steel materrial. CNC routers use CAM software programmes, a visual programming tool for creating geometric code, or simply, g-code, the CNC computer language that controls the CNC machines, as an advanced sort of tooling approach. G-code directs the fundamental timing, direction, and movement of the machine tool heads. In the production process known as CNC turning, material bars are held in a chuck and rotated while a tool is being fed to the piece to remove material until the required form is attained. Subtraction machining is another name for the process, which involves removing material in order to create the required shape. The cutting tool sized used is 3mm diameter that was suitable to cut our composite speciment smoothly. An electric motor provides the power required to run a CNC router machine. Figure 3.23 shows that the CNC router macchine model MODELA PRO2 (MDX-540) as in the FTK laboratory.

Figure 3.23 CNC router macchine model MODELA PRO2 (MDX-540)

3.5.3 Impact Testing

The impact characteristics energy of the produced composites was calculated in accordance with ASTM E23. The test specimens were cut into lengths of 55m, widths of 12.5mm, and thicknesses of 10mm. They were also cut to a thickness of 10mm. A V notch must be cut into the specimen before the impact process can begin. When the angle is 45 degrees, the depth of the V notch is 3mm. The Charpy impact test is one type of impact test that is used. Figure 3.9 depicts the charpy impact INSTRON CEAST 9050 machine at the FTK laboratory.

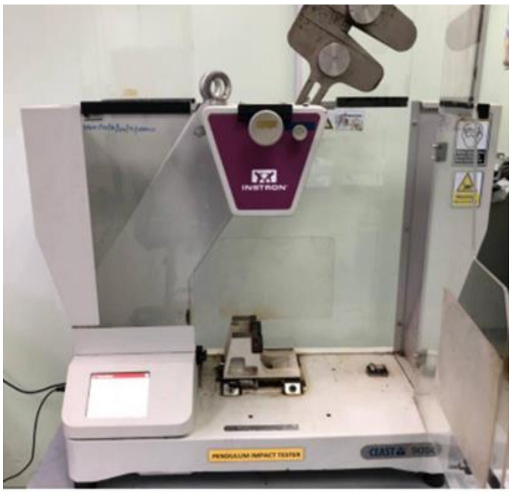


Figure 3.24 The charpy impact INSTRON CEAST 9050 machine

3.5.4 Tensile Testing

The tensile properties of the fabricated composites (ultimate tensile strength, strain to failure, and Young's modulus) were calculated using ASTM D3039 at a cross-head speed of 5mm/min. The test specimens were cut into strips that were 120mm long and 20mm wide. The universal testing machine SHIMADZU model is shown in Figure 3.24 at the FTK laboratory.

Figure 3.25 The universal testing machine (SHIMADZU)

3.5.5 Flexural Testing

Flexural testing is used to determine the material's flex properties. The properties of flexural strength and flexural modulus in the fabricated composites were calculated using ASTM D790-07 at a cross-head speed of 2mm/min. The test specimens were cut into strips that were 120 mm long, 20 mm wide, and 3 mm thick. It entails placing a specimen 60mm apart between two points or supports and initiating a load with a third point. Figure 3.11 depicts the universal testing machine SHIMADZU model used for flexural testing at the FTK laboratory.

Figure 3.26 The universal testing machine (SHIMADZU)

3.5.6 Statistically Analysed (ANOVA)

The results are then statistically analysed in the final stage. Based on the mechanical property analysis results, we will determine the best ratio of pineapple leaf powder reinforced by polyester resin. ANOVA is a statistical method for determining whether or not the averages of samples from the same population are the same. In this study, expanding ANOVA is used to calculate the loss function using the anova one-way ratio at each treatment level. It should include more information to help choose the best ratio of pineapple leaf reinforced polyester resin composite ratio.

3.6 Summary

To meet all of the project's objectives, all of these procedures and preparations must be carried out properly and in accordance with the process planning. By the end of this chapter, you will understand how important planning, method, and preparation are in achieving outcomes and performance. Finally, in order to obtain accurate results from these tests, all methods must be followed precisely and without errors.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This is the section where we will talk about the strength of composites. The pineapple leaf and polyester resin composite will be tested using three different methods: impact testing, tensile testing, and flexural testing. For specimen size, all testing methods add here to ASTM standards. This chapter will analyse and explain the results of numerous tests performed, as well as the computation used.

4.2 Sample Size

Scanning Electron Microscope (SEM) is a high-resolution electron microscopy technique that provides more information about nanomaterials by probing samples on a very fine scale with a high electron beam. Fabrication composites of PLPR were prepared by using the hand mixing technique. The matrix system was prepared by mixing the resin and the hardener in a ratio of 1:1. Figure 4.1 shows the sample size measure by stereo microscope SMZ754T . Whereas the Stereo microscope SMZ754T was used to determine the size of the pineapple leaf powder and the result of data measurements are shown in Table 4.1.

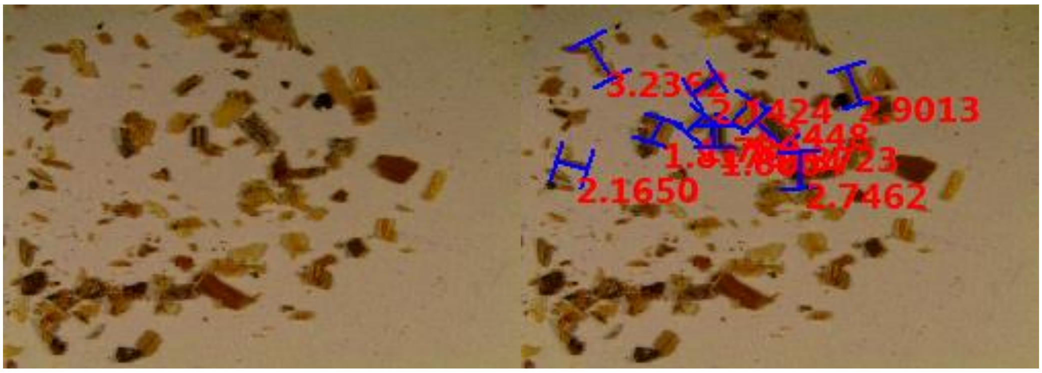


Figure 4.1 Sample size measured

Table 4.1 Average size of pineapple leaf powder

Sample	Mean(mm)	Min	Max	Sum	std. Dev	Variance
A	2.3507	1.6004	3.2363	23.5070	0.5555	0.3086
B	2.1382	1.5098	2.7174	21.3824	0.3591	0.1289
C	2.6358	1.5151	3.6496	26.3579	0.6690	0.4476
Avearage	2.3749	1.5418	3.2011	23.7491	0.5279	0.2950

4.3 Impact Test Result

This Figure 4.1 illustrates the specimen of the impact test before and after testing. There are 25 samples for each of five eco-friendly PLPR composites ratio of 20PL80PR, 40PL60PR, 50PL60PR, 60PL40PR and 80PL20PR that were tested by using Universal Testing Machine.

a) Before test

b) After test

Figure 4.2 Specimen before and after test

Determining the strength ratio of pineapple leaf reinforced with polyester resin is the aim of this experiment as a result. The results indicated that PLPR60 composite, as opposed to other composites with various ratios (i.e. PLPR20, PLPR40, PLPR50, and PLPR80), had the maximum absorb energy with (2.53 J) as shown in Figure 4.2. Comparatively, the impactstrength was lowest at the biggest ratio, PLPR80 . This observation suggest that the increase of ratio of nature material until 60 make more stronger and the strength decrease after that. The absorb energy of composite materials is determined mostly by the strength and volume content of the fibre reinforcement. The breaking strength of the fibres is much greater than the strength of the polymer matrix, and therefore the fibres determine the ultimate strength of the composite.

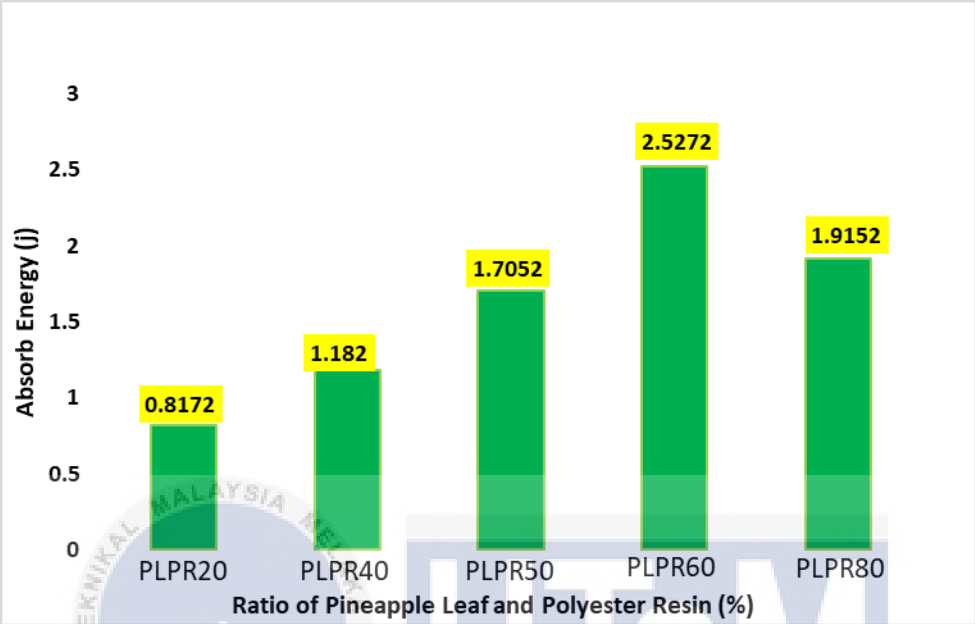


Figure 4.3 Absorb energy for various ratio of pineapple leaf reinforced polyester resin

This observation suggested that the impact strength of the eco-friendly ratio of PLPR 60 was the strongest. Then, a one-way analysis of variance (ANOVA) was applied to analyze the absorb energy of the PLPR composites as shown in Table 4.1. The results presented that the absorb energy of PLPR composites for all five eco-friendly ratio were significant since the P-value is lower than the significant cut-off level which is α = 0.05. Therefore, it indicated that all absorb energy for five eco-friendly ratio of PLPR composites have a different averages. As an outcome the best absorb energy is combination of 60% of pineapple leaf and 40% polyester resin mixture.

Table 4.2 ANOVA of absorb energy for five eco-friendly ratio of PLPR composites.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Absorb Energy	8.766539	4	2.191635	101.556	5.45E-13
Error	0.431611	20	0.021581		
Total	9.19815	24			

SS = Sum of Square, df = Degree of Freedom, MS = Mean Square, F= Test Statistic

Using Turkey's test, two mean are demand to be substantially different if their sample difference's absolute values is greater. To illustrate Turkey's test, we use the data from the plasma etching experiment in Table 4.1 with α = 0.05 and f =20 degrees of freedom for error. From Table VII (see Douglass C et al., 2023) $q_{0.05}$ (5,20) = 4.24 . Therefore, we have,

$$T_{\alpha = q_{\alpha}}(\alpha, f)\sqrt{\frac{MS_E}{n}} = T_{\alpha = q_{0.05}}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{0.021581}{5}} = 0.2786$$

From the calculation, any pairs of treatment averages with absolute value differences more than 0.2786 would suggest that the associated pair of population mean is significantly different. The five treatment averaging results are as follows :

$$\bar{y}_{1.} = 0.8172$$
$$\bar{y}_{2.} = 1.182$$
$$\bar{y}_{3.} = 1.7052$$
$$\bar{y}_{4.} = 2.5272$$
$$\bar{y}_{5.} = 1.9152$$

$\overline{y}_{1.} - \overline{y}_{2.} = 0.8172 - 1.182 = -0.3648^{*}$

$\overline{y}_{1.} - \overline{y}_{3.} = 0.8172 - 1.7052 = -0.888^{*}$

$\overline{y}_{1.} - \overline{y}_{4.} = 0.8172 - 2.5272 = -1.71^{*}$

$\overline{y}_{1.} - \overline{y}_{5.} = 0.8172 - 1.9152 = -1.098^{*}$

$\overline{y}_{2.} - \overline{y}_{3.} = 1.182 - 1.7052 = -0.52^{*}$

$\overline{y}_{2.} - \overline{y}_{4.} = 1.182 - 2.5272 = -1.3452^{*}$

$\overline{y}_{2.} - \overline{y}_{5.} = 1.182 - 1.9152 = -0.7332^{*}$

$\overline{y}_{3.} - \overline{y}_{4.} = 1.7052 - 2.5272 = -0.822^{*}$

$\overline{y}_{3.} - \overline{y}_{5.} = 1.7052 - 1.9152 = -0.21$

The pairs of means with significantly different starred values are shown by the starred values. The Turkey procedure, it should be noted, shows that all pairs of means are different. Consequently, the mean etch rate at any power setting is different from the mean etch rate at any other power setting.

4.4 Tensile Test Result

Figure 4.2 illustrates the specimen of the tensile test before and after testing. There are 25 samples for each of five eco-friendly PLPR composites ratio of 20PL80PR, 40PL60PR, 50PL60PR, 60PL40PR and 80PL20PR that were tested by using Universal Testing Machine.

a) Before test

b) After test

Figure 4.4 Tensile test specimen before and after test

Figure 4.4 illustrates the tensile strength values for each of the five different ratio eco-friendly PLPR composites. Meanwhile, Figure 4.5 shows the elasticity value for each of five different ratio eco-friendly PLPR composites. There were five different ratios used that was 20PL80PR, 40PL60PR, 50PL50PR, 60PL40PR and 80PL20PR. The tensile strength and elasticity of 60PL40PR were found to be higher than other PLPR composite ratios. Comparatively, 20PL80PR had the lowest value of tensile strength and elasticity. This observation suggested that the tensile strength of the eco-friendly ratios of PLPR composites become stronger as the percentage of pineapple leaf is around 60%. The tensile strength and elastic force of composite materials is determined mostly by the strength and volume content of the fibre reinforcement. The breaking strength of the fibres is much greater than the strength of the polymer matrix, and therefore the fibres determine the ultimate strength of the composite.

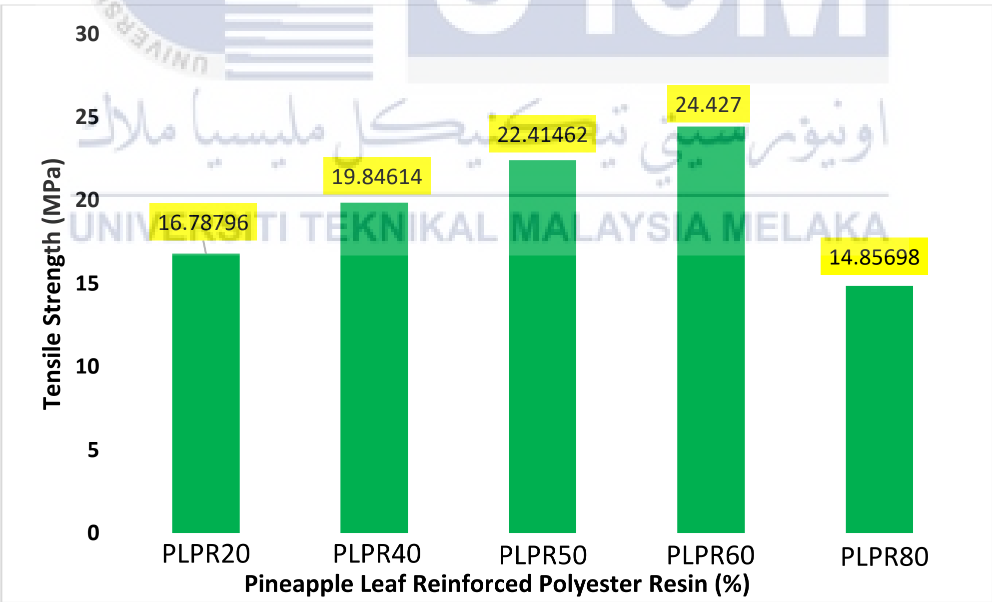


Figure 4.5 Tensile strength value for five different ratio of PLPR

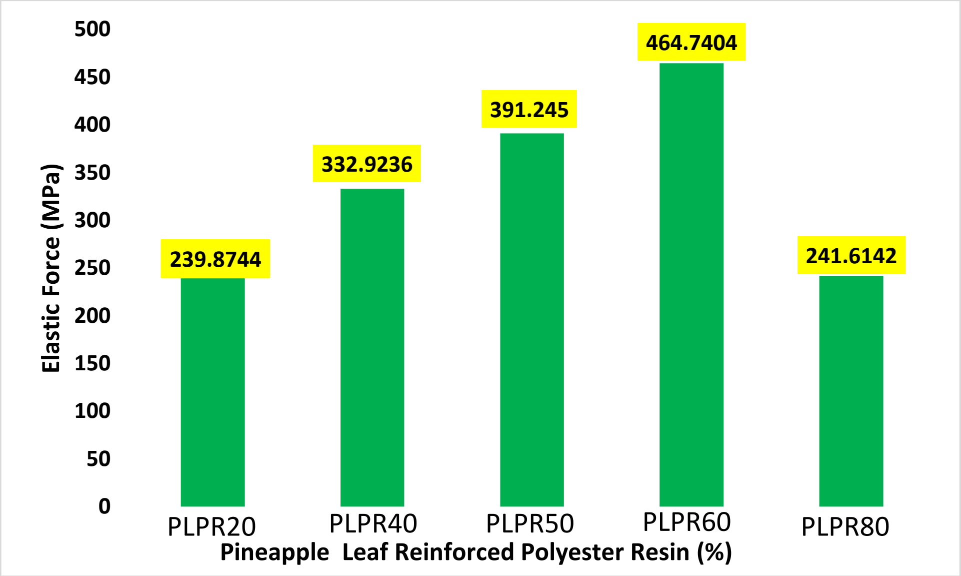


Figure 4.6 Elactic force value for five different ratio of PLPR

Then, a one-way analysis of variance (ANOVA) was applied to analyze the tensile strength and elasticity of the PLPR composites as shown in Table 4.2 and Table 4.3, respectively. The results presented that the tensile strength and elasticity of PLPR composites for all five eco-friendly ratios were significant since the P-value is lower than the significant cut-off level which is α = 0.05. Therefore, it indicated that all the tensile strength and elasticity for five eco-friendly ratios of PLPR composites have a different averages. Asa na outcome, the best tensile properties are obtained by combining pineapple leaf and polyester resin matrix in proportionf of 60% and 40% respectively.

Table 4.3 ANOVA of tensile strength for five eco-friendly ratio of PLPR composites.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Tensile Strength	308.3213	4	77.08034	18.59242	1.62E-06
Error	82.91586	20	4.145793		
Total	391.2372	24			

SS = Sum of Square, df = Degree of Freedom, MS = Mean Square, F = Test Statistic

Using Turkey's test, two mean are demand to be substantially different if their sample difference's absolute values is greater. To illustrate Turkey's test, we use the data from the plasma etching experiment in Table 4.2. with α = 0.05 and f =20 degrees of freedom for error. From Table VII (see Douglass C et al., 2023) $q_{0.05}$ (5,20) = 4.24 . Therefore, we have,

$$T_{\alpha = q_\alpha}(\alpha, f)\sqrt{\frac{MS_E}{n}} = T_{\alpha = q_{0.05}}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{4.145793}{5}} = 3.861$$

Using therefore, any pairs of treatment averages with absolute value differences more than 3.861 would suggest that the associated pair of population mean is significantly different. The five treatment averaging results are as follows :

$\overline{y}_{1.}$ = 16.78796

$\overline{y}_{2.}$ = 19.84614

$\overline{y}_{3.}$ = 22.41462

$\overline{y}_{4.}$ = 24.427

$\overline{y}_{5.}$ = 14.85698

$\overline{y}_{1.}$ - $\overline{y}_{2.}$ = 16.78796 – 19.84614 = -3.05818

$\overline{y}_{1.}$ - $\overline{y}_{3.}$ = 16.78796 - 22.41462 = -5.62666 *

$\overline{y}_{1.}$ - $\overline{y}_{4.}$ = 16.78796 - 24.427 = -7.63904*

$\overline{y}_{1.}$ - $\overline{y}_{5.}$ = 16.78796 - 14.85698 = - 1.93098

$\overline{y}_{2.}$ - $\overline{y}_{3.}$ = 19.84614 - 22.41462 = -2.56848

$\overline{y}_{2.}$ - $\overline{y}_{4.}$ = 19.84614 - 24.427 = - 4.58086*

$\overline{y}_{2.}$ - $\overline{y}_{5.}$ = 19.84614 -14.85698 = -4.98916*

$\overline{y}_{3.}$ - $\overline{y}_{4.}$ = 22.41462 - 24.427 = -2.01238

$\overline{y}_{3.}$ - $\overline{y}_{5.}$ = 22.41462 - 14.85698 = 7.55764*

Using the pairs of means with significantly different are shown by the starred values. The Turkey procedure, it should be noted, shows that all pairs of means are different. Consequently, the mean etch rate at any power setting is different from the mean etch rate at any other power setting.

Table 4.4 ANOVA of elasticity for five eco-friendly ratio of PLPR composites

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Elastic Force	188829.7	4	47207.42	47.51235	6.15E-10
Error	19871.64	20	993.582		
Total	208701.3	24			

SS = Sum of Square, df = Degree of Freedom, MS = Mean Square, F = Test Statistic

Using Turkey's test, two mean are demand to be substantially different if their sample difference's absolute values is greater. To illustrate Turkey's test, we use the data from the plasma etching experiment in Table 4.2. with α = 0.05 and f =20 degrees of freedom for error. From Table VII (see Douglass C et al., 2023) $q_{0.05}$ (5,20) = 4.24 . Therefore, we have,

$$T_{\alpha= q_\alpha}(\alpha, f)\sqrt{\frac{MS_E}{n}} = T_{\alpha= q_{0.05}}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{993.582}{5}} = 59.769$$

Using therefore, any pairs of treatment averages with absolute value differences more than 59.769 would suggest that the associated pair of population mean is significantly different. The five treatment averaging results are as follows :

$$\bar{y}_{1.} = 239.8744$$
$$\bar{y}_{2.} = 332.9236$$
$$\bar{y}_{3.} = 391.245$$
$$\bar{y}_{4.} = 464.7404$$
$$\bar{y}_{5.} = 241.6142$$

$$\bar{y}_{1.} - \bar{y}_{2.} = 239.8744 – 332.9236 = -93.0492^*$$
$$\bar{y}_{1.} - \bar{y}_{3.} = 239.8744 - 391.245 = -151.3706^*$$

$$\overline{y}_{1.} - \overline{y}_{4.} = 239.8744 - 464.7404 = -224.866^*$$

$$\overline{y}_{1.} - \overline{y}_{5.} = 239.8744 - 241.6142 = -1.7398$$

$$\overline{y}_{2.} - \overline{y}_{3.} = 332.9236 - 391.245 = -58.3214$$

$$\overline{y}_{2.} - \overline{y}_{4.} = 332.9236 - 464.7404 = -131.8168^*$$

$$\overline{y}_{2.} - \overline{y}_{5.} = 332.9236 - 241.6142 = -91.3094^*$$

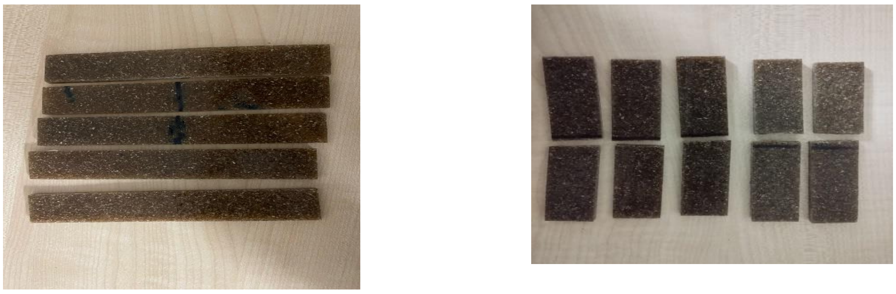
$$\overline{y}_{3.} - \overline{y}_{4.} = 391.245 - 464.7404 = -73.4954^*$$

$$\overline{y}_{3.} - \overline{y}_{5.} = 391.245 - 241.6142 = 149.6308^*$$

Using the pairs of means with significantly different are shown by the starred values. The Turkey procedure, it should be noted, shows that all pairs of means are different. Consequently, the mean etch rate at any power setting is different from the mean etch rate at any other power setting.

4.5 Flexural Test Result

Figure 4.2 illustrates the specimen of the flexural test before and after testing. There are 25 samples for each of five eco-friendly PLPR composites ratio of 20PL80PR, 40PL60PR, 50PL60PR, 60PL40PR and 80PL20PR that were tested by using Universal Testing Machine.



a) Before test

b) After test

Figure 4.7 Flexural test specimen before and after test

Figure 4.7 illustrates the flexural maximum force values for each of the five different ratio eco-friendly PLPR composites. Meanwhile, Figure 4.8 shows the maximum stress value for each of five different ratio eco-friendly PLPR composites. There were five different ratios used that was 20PL80PR, 40PL60PR, 50PL50PR, 60PL40PR and 80PL20PR. The tensile strength and elasticity of 60PL40PR were found to be higher than other PLPR composite ratios. Comparatively, 20PL80PR had the lowest value of maximum force and maximum stress. This observation suggested that the flexural strength of the eco-friendly ratios of PLPR composites become stronger as the percentage of pineapple leaf is around 60%. The volume and strength of the fiber reinforcement play a major role in determining the maximum force and maximum stress of composite materials. The fibers decide the composite's ultimate strength since their breaking strength is substantially higher than the strength of the polymer matrix.

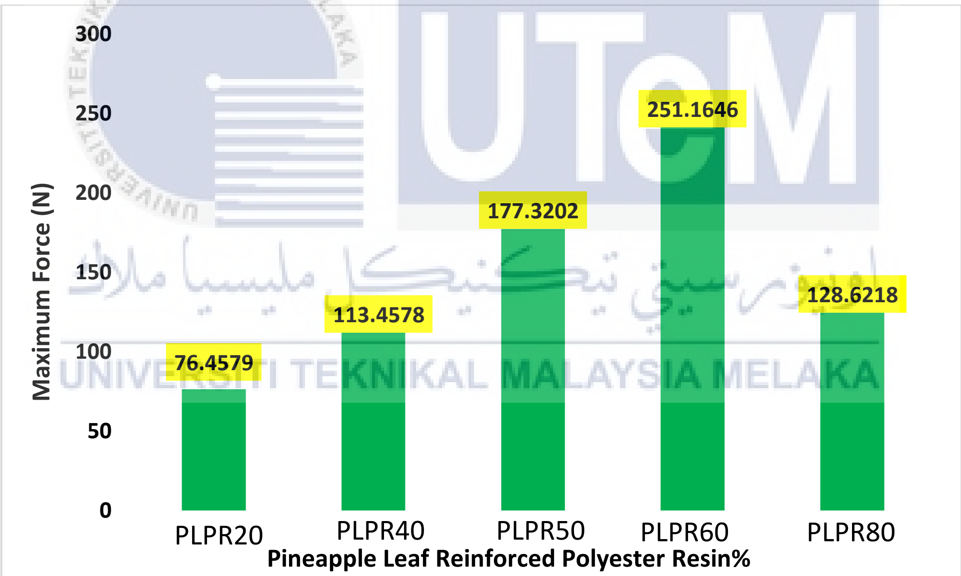


Figure 4.8 Maximum force value for five different ratio of PLPR

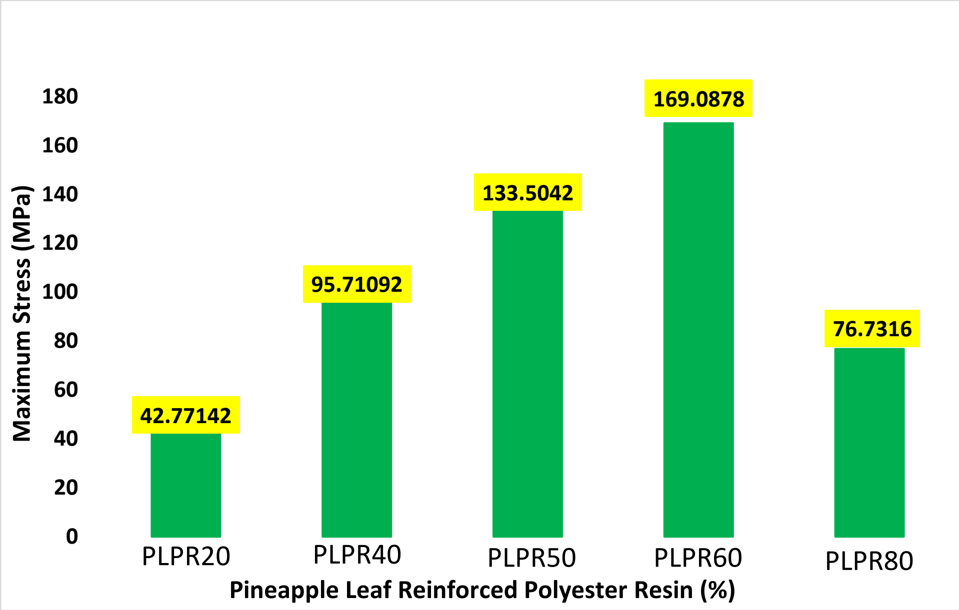


Figure 4.9 Maximum stress value for five different ratio of PLPR

Then, a one-way analysis of variance (ANOVA) was applied to analyze the flexural strength and elasticity of the PLPR composites as shown in Table 4.2 and Table 4.3, respectively. The results presented that the maximum force and maximum stress of PLPR composites for all five eco-friendly ratios were significant since the P-value is lower than the significant cut-off level which is α = 0.05. Therefore, it indicated that all the tensile strength and elasticity for five eco-friendly ratios of PLPR composites have a different averages. Asa na outcome, the best flexural properties are obtained by combining pineapple leaf and polyester resin matrix in proportionf of 60% and 40% respectively.

Table 4.5 ANOVA of maximum focrce for five eco-friendly ratio of PLPR composites.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Maximum Force	90898.48	4	22724.62	63.73536	4.26E-11
Error	7130.931	20	356.5465		
Total	98029.41	24			

SS = Sum of Square, df = Degree of Freedom, MS = Mean Square, F = Test Statistic

Using Turkey's test, two mean are demand to be substantially different if their sample difference's absolute values is greater. To illustrate Turkey's test, we use the data from the plasma etching experiment in Table 4.4. with α = 0.05 and f =20 degrees of freedom for error.From Table VII (see Douglass C et al., 2023) $q_{0.05}$ (5,20) = 4.24 . Therefore, we have,

$$T_{\alpha= q_{\alpha}}(\alpha, f)\sqrt{\frac{MS_E}{n}} = T_{\alpha= q_{0.05}}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{356.5465}{5}} = 35.805$$

Using therefore, any pairs of treatment averages with absolute value differences more than 35.805 would suggest that the associated pair of population mean is significantly different. The five treatment averaging results are as follows :

$\overline{y}_{1.}$ = 76.4579

$\overline{y}_{2.}$ = 113.4578

$\overline{y}_{3.}$ = 177.3202

$\overline{y}_{4.}$ = 251.1646

$\overline{y}_{5.}$ = 128.6218

$\overline{y}_{1.}$ - $\overline{y}_{2.}$ = 76.4579 – 113.4578 = -36.999*

$\overline{y}_{1.}$ - $\overline{y}_{3.}$ = 76.4579 - 177.3202 = -100.862 *

$\overline{y}_{1.}$ - $\overline{y}_{4.}$ = 76.4579 - 251.1646 = -174.707*

$\overline{y}_{1.}$ - $\overline{y}_{5.}$ = 76.4579 - 128.6218 = - 52.164*

$\overline{y}_{2.}$ - $\overline{y}_{3.}$ = 113.4578 - 177.3202 = -63.862*

$\overline{y}_{2.}$ - $\overline{y}_{4.}$ = 113.4578 - 251.1646 = - 137.707*

$\overline{y}_{2.}$ - $\overline{y}_{5.}$ = 113.4578 - 128.6218 = - 15.164

$\overline{y}_{3.}$ - $\overline{y}_{4.}$ = 177.3202 - 251.1646 = -73.844*

$\overline{y}_{3.}$ - $\overline{y}_{5.}$ = 177.3202 - 128.6218 = 48.698*

Using the pairs of means with significantly different are shown by the starred values. The Turkey procedure, it should be noted, shows that all pairs of means are different. Consequently, the mean etch rate at any power setting is different from the mean etch rate at any other power setting.

Table 4.6 ANOVA of maximum stress for five eco-friendly ratio of PLPR composites.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*
Maximum Stress	48335.85	4	12083.96	85.1017	2.89E-12
Error	2839.888	20	141.9944		
Total	51175.74	24			

SS = Sum of Square, df = Degree of Freedom, MS = Mean Square, F = Test Statistic

Using Turkey's test, two mean are demand to be substantially different if their sample difference's absolute values is greater. To illustrate Turkey's test, we use the data from the plasma etching experiment in Table 4.2. with α = 0.05 and f =20 degrees of freedom for error. From Table VII (see Douglass C et al., 2023) $q_{0.05}$ (5,20) = 4.24 . Therefore, we have,

$$T_{\alpha = q_\alpha}(\alpha, f)\sqrt{\frac{MS_E}{n}} = T_{\alpha = q_{0.05}}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{141.9944}{5}} = 22.595$$

Using therefore, any pairs of treatment averages with absolute value differences more than 22.595 would suggest that the associated pair of population mean is significantly different. The five treatment averaging results are as follows :

$$\bar{y}_{1.} = 42.77142$$

$$\overline{y}_{2.} = 95.71092$$

$$\overline{y}_{3.} = 133.5042$$

$$\overline{y}_{4.} = 169.0878$$

$$\overline{y}_{5.} = 76.7316$$

$$\overline{y}_{1.} - \overline{y}_{2.} = 42.77142 - 95.71092 = -52.939$$

$$\overline{y}_{1.} - \overline{y}_{3.} = 42.77142 - 133.5042 = -90.769 *$$

$$\overline{y}_{1.} - \overline{y}_{4.} = 42.77142 - 169.0878 = -126.316*$$

$$\overline{y}_{1.} - \overline{y}_{5.} = 42.77142 - 76.7316 = -33.960*$$

$$\overline{y}_{2.} - \overline{y}_{3.} = 95.71092 - 133.5042 = -37.793*$$

$$\overline{y}_{2.} - \overline{y}_{4.} = 95.71092 - 169.0878 = -73.377*$$

$$\overline{y}_{2.} - \overline{y}_{5.} = 95.71092 - 76.7316 = -18.979$$

$$\overline{y}_{3.} - \overline{y}_{4.} = 133.5042 - 169.0878 = -35.584*$$

$$\overline{y}_{3.} - \overline{y}_{5.} = 133.5042 - 76.7316 = 56.773*$$

Using the pairs of means with significantly different are shown by the starred values. The Turkey procedure, it should be noted, shows that all pairs of means are different. Consequently, the mean etch rate at any power setting is different from the mean etch rate at any other power setting.

CHAPTER 5

CONCLUSION AND RECOMENDATION

5.1 Introduction

This chapter summarises the findings and offers suggestions for further research for this experiment. The goal of this study was to use three different testing procedureis impact testing, tensile testing, and flexural testing to improve the data on how to archive a good quality of strength material on pineapple leaf reinforced polyester resin composite.

5.2 Conclusion

Three goals must be met for this research to be successful, as was indicated in the previous chapter. Mechanical characteristics of the composite for filler components such leftover pineapple trash that was pineapple leaves. The specimen was made by combining various amounts of pineapple leaf (PL) with polyester resin, including 20% PL and 80% polyester resin, 40% PL and 60% polyester resin, 50% PL and 50% polyester resin, 60% PL and 40% polyester resin, and 80% PL and 20% polyester resin. Pineapple leaf waste-reinforced polyester resin has been developed successfully. Since the investigation on mechanical characteristics utilising the tensile test, impact test, and flexural on the PLPR was successful, everything described has been archived for this experiment. Utilizing

This study has looked at how PLPR composites affect in different ratios and their mechanical characteristics. The initial stage was to create the specimen using the prior study as a guide, and the ASTM standard was then employed for the experiment. In addition, the mould has been ready. All specimens are tested in accordance with the ASTM standard in three different ways: impact, tensile, and flexural tests. Depending on the procedure that will be used, this experiment has two different designs mold. The design was made by chopping up and cruching the original design and building a new one. This strategy will reduce production costs and time. The process that will be used to make sure that the specimen's dimensions match the machine exactly and that it is tested informed the design of this experiment. The specimen was then constructed utilising the hand mixed lay-up method. It is crucial to confirm that the specimen was produced with high-quality materials. The preparation of the mould and the hand-lay-up technique for doing the hand-lay-up are just two of the many procedures used to maintain control over the production process's quality. For this experiment, there are five different ratios: 20% PL and 80% polyester resin (PLPR20), 40% PL and 60% polyester resin (PLPR40), 50% PL and 50% polyester resin (PLPR50), 60% PL and 40% polyester resin (PLPR60), and 80% PL and 20% polyester resin (PLPR80) of CCSP composite. The idea is to increase the amount of natural material in the composite.

The mechanical characteristics of the experimental material have undergone impact testing. Impact testing high when increase the PLPR composite ratio and the amount of energy placed on the specimen. It was the strength increase until ratio 60% of pineapple leaf reinforced polyester resin and come down again in 80% of pineapple leaf reinforced polyester resin. The results indicate that the PLPR60 composite has the highest energy absorption capacity, with a value of 2.5272 J. Additionally, according to the ANOVA results, all of the PLPR composites' absorb energies were significant.

Beside that, the mechanical characteristics of the experimental material have been tested using tensile methods. I used the maximal strength and elastic force as my major tensile testing results. Tensile testing revealed that pineapple leaf reinforced polyester resin, at 60%, had the maximum tensile strength. Based on my goal, which is to fabricate recycled pineapple leaf waste, the attention is mainly on combined waste materials. When the PLPR composite ratio is 60%, according to five ratio tests, the highest tensile strength is obtained. The highest average for elastic force is 464.74 MPa, while the highest average for maximum strength PLPR60 is 24.427MPa. Furthermore, according to the ANOVA results, all of the PLPR composites' tensile strengths were significant.

Third, tests on the mechanical characteristics of the experimental material's flexural strength have been conducted. I used the maximum stress and maximum force as my principal flexural testing results. Flexural tests found that pineapple leaf reinforced polyester resin, at 60%, has the maximum strength. Based on my goal, which is to build recycled pineapple leaf , the concentration is mainly on mixed waste materials. When the PLPR composite ratio is 60%, according to five ratio tests, the highest flexural strength is produced. The highest average for maximum stress is 169.08MPa , while the highest average for maximum force PLPR60 is 251.165 N. The ANOVA findings also showed that all flexural strengths of the PLPR composites were significant.

According to the study, as the ratio rises, PLPR composites achieve their peak tensile strength at 60% and then begin to decline at 80%. Additionally, according to the ANOVA results, all of the PLPR composites' impact, tensile, and flexural testing results were noteworthy. As per study on PLPR composites, the composite with 60% pineapple leaf and 40% polyester resin was much stronger and had the highest tensile strength and flexural strength. 60% of PLPR have the most impact energy. All of the specimen PLPR composite ratios have been statistically analysed. For the show the significant have use the turkey test to declare all the different in the data.Since PLPR composites lead to higher exploitation of already-existing natural fibres and their composites will be advantageous to the country's economy, it may be argued that the acquired outcomes of PLPR composites are not negotiable and may be of potential value.

5.3 Recommendation

There are suggestions in this paper that might be helpful. analysis of the PLPR composite's composition and the various ratios found in this study. According to this study, PLPR composites with 60% have higher tensile strength. It was established that the 60% (PLPR60) specimen had a high average tensile strength and was an appropriate choice. Additionally, it demonstrated the strong flexural strength of the 60% (PLPR60) specimen. It won't suggest another ratio, such as one that is higher than 65% (PLPR65), to determine which ratio is stronger because (PLPR80) was lower than (PLPR60). There are issues that will necessitate specimen thickness when the PLPR ratio is at its peak during the operation. To analyze more mechanical properties of PLPR composite, however, apply an additional tactical method such compress testing, SEM, and hardness testing. Study the hand-mixed composite's composition next for a better outcome and material performance. Additionally, tables, picture frames, and closet frames can be made from these composites. Its application in modern times is becoming more widespread and now includes electrical housing, home appliances, architecture and construction, and food packaging. Since PLPR composites lead to higher exploitation of already-existing natural fibers and their composites will be advantageous to the country's economy, it may be argued that the acquired outcomes of PLPR composites are not negotiable and may be of potential value.

5.4 Project Potential

All future enhancements and modifications that a product might experience are included in its potential. A company must strive to surprise and please customers in the future by continuing to enhance products to ensure future client loyalty. Pineapple leaf composites are therefore used in a variety of automobile applications, including the production of dashboards, package trays, door panels, headliners, seats, seat backs, and several other interior components.

Lingo-cellulosic fibers are seen in pineapple leaves. Low density fibers are present in it. For the creation of reinforced polyethylene composites, it is overwhelmingly chosen. In addition to fiber damage and breakage during melt mixing, electro-microscope research demonstrates that fibers are correctly orientated during the composite construction process. As a result, pure polyester exhibits brittle stress-strain behavior under tension, and the inclusion of fillers makes the matrix more ductile. It was related to my study, and I have proved the strength of pineapple leaf reinforced polyester resin with three different testing.

By itself, pineapple leaf produces a sheer, rigid, light-weight material that is ideal for usage in subtropical climes for traditional formal attire and accessories. It is the most robust material used as a substitute for leather in clothing, footwear, and accessories. It will help us to reduce the cost to buy raw material and can just use the environmental waste that was pineapple leaf to produce the quality Texas product.

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APPENDICES

APPENDIX A Gantt chart for PSM 1

No	Project Task	Actual / Plan	Week													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of supervisor and PSM title	Plan	X													
		Actual														
2	Briefing of PSM title	Plan		X												
		Actual														
3	Discussing problem statement and objective for the chapter I	Plan			X											
		Actual														
4	Research and writing of chapter 2, literature review	Plan				X	X	X	X							
		Actual														
5	Submit and present progression for chapter 2	Plan								X						
		Actual														
6	Research and writing of chapter 3, methodology	Plan								X	X					
		Actual														
7	Writing chapter 4 and , expected outcome	Plan										X				
		Actual														
8	Submission of PSM I first draft	Plan											X			
		Actual														
9	Submission of PSM I second draft	Plan												X		
		Actual														
10	Preparation and presentation of PSM I	Plan														X
		Actual														

APPENDIX B Gantt chart for PSM 2

No	Project Task	Actual / Plan	Week													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Discussing and planning tasks with the supervisor	Plan	X													
		Actual														
2	Purchase raw materials and necessary equipment	Plan	X													
		Actual														
3	Fabricating process	Plan			X	X	X									
		Actual														
4	Testing	Plan						X	X							
		Actual														
5	Data analysis	Plan								X						
		Actual														
6	Research and writing of chapter 4, result and discussion	Plan									X	X				
		Actual														
7	Research and writing of chapter 5, conclusion, and recommendations	Plan										X				
		Actual														
8	Submission of PSM 2 first draft	Plan										X	X			
		Actual														
9	Submission of PSM 2 second draft	Plan											X			
		Actual														
10	Preparation and presentation of PSM 2	Plan												X		
		Actual														