UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EXPERIMENTAL ANALYSIS ON MECHANICAL PROPERTIES OF COCONUT LEAF REINFORCED POLYESTER RESIN

WELLDEN ANAK HENRY

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 fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project entitled "EXPERIMENTAL ANALYSIS ON MECHANICAL PROPERTIES OF COCONUT LEAF REINFORCED POLYESTER RESIN" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : *WELLDEN ANAK HENRY*

Date : 09 January 2023

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

Signature :

Supervisor Name : *DR ISKANDAR BIN WAINI*

Date : 20 January 2023

DEDICATION

All 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 program. A special award, I dedicate this thesis to my dear parents, Mr. Henry Anak Raden and Mrs. Domy Anak Jago. Finally, I'd like to thank my supervisor, Dr. Iskandar Bin Waini and my co-supervisor, Ts. Dr. Khairum Bin Hamzah, for all of his help, guidance, and advice in completing this thesis.

ABSTRACT

In order to protect the environment by using biodegradable materials, natural fibres have become more frequently used in composites. Due to their high specific strength and modulus, fibre reinforced polymer-based composites have been employed in numerous industrial applications for a very long time. Since there are numerous natural fibres accessible, it was decided to investigate using coir, a natural fibre, as reinforcement in reinforced polymers. The strength and lightness of natural fibres are matched by their affordability. Therefore, the objective of the present study is to investigate the mechanical properties of coconut leaf reinforced polyester resin. This project will be carried out by the fabrication of the materials by using the hand lay-up technique. Then, the cutting of fabricated materials by using CNC router machine according to the ASTM standards. After completely done the cutting process, it will test through tensile, flexural, and impact tests to determine the mechanical properties of the samples. The collected data were analysed using statistical analysis. Based on the tensile, flexural, and impact properties of coconut leaf reinforced polyester resin, it shows that for coconut leaf reinforced polyester resin ratios of 40CL60PR have better tensile strength (22.57674 MPa) and elasticity (694.5164 MPa), flexural load of maximum force (178.6082 MPa) and flexural load of stress (93.09764 MPa),and impact strength (0.288 Joule) compared to the other eco-friendly ratios of coconut leaf reinforced polyester resin which are 20CL80PR, 50CL50PR, 60CL40PR, and 80CL20PR respectively. Then, a one-way analysis of variance (ANOVA) was applied to analyze the tensile strength and elasticity, flexural load of maximum force and maximum stress, and impact strength of the CLPR composites. The results presented that the mechanical properties of CLPR composites for all five eco-friendly ratios were significant since the P-value is lower than the significant cut-off level which is $\alpha = 0.05$. Therefore, it indicated that the mechanical properties for five eco-friendly ratios of CLPR composites has different averages.

ABSTRAK

Untuk melindungi alam sekitar dengan menggunakan bahan terbiodegradasi, gentian semulajadi telah menjadi lebih kerap digunakan dalam komposit. Oleh kerana kekuatan dan modulus spesifiknya yang tinggi, komposit berasaskan polimer bertetulang gentian telah digunakan dalam pelbagai aplikasi perindustrian untuk masa yang sangat lama. Oleh kerana terdapat banyak gentian semula jadi yang boleh diakses, ia telah memutuskan untuk menyiasat menggunakan sabut, gentian asli, sebagai tetulang dalam polimer bertetulang. Kekuatan dan ringan gentian semulajadi dipadankan dengan kemampuannya. Oleh itu, objektif kajian ini adalah untuk menyiasat sifat mekanikal resin poliester bertetulang daun kelapa. Projek ini akan dijalankan secara fabrikasi bahan dengan menggunakan teknik penghasilan bahan komposit. Kemudian, pemotongan bahan fabrikasi dengan menggunakan mesin penghala CNC mengikut piawaian ASTM. Selepas selesai proses pemotongan, ia akan menguji melalui ujian tegangan, lenturan dan hentaman untuk menentukan sifat mekanikal sampel. Data yang dikumpul dianalisis menggunakan analisis statistik.Berdasarkan sifat tegangan, lentur dan hentaman resin poliester bertetulang daun kelapa, ia menunjukkan bahawa bagi nisbah resin poliester bertetulang daun kelapa 40CL60PR mempunyai kekuatan tegangan yang lebih baik (22.57674 MPa) dan keanjalan (694.5164 MPa), daya lentur (beban lentur maksimum) (178.6082 MPa) dan beban lenturan tegasan (93.09764 MPa), dan kekuatan hentaman (0.288 Joule) berbanding nisbah mesra alam yang lain bagi resin poliester bertetulang daun kelapa iaitu antaranya 20CL80PR, 50CL50PR, 60CL40PR20PR dan 80CL40PR8. Kemudian, analisis varians sehala (ANOVA) digunakan untuk menganalisis kekuatan tegangan dan keanjalan, beban lentur daya maksimum dan tegasan maksimum, dan kekuatan hentaman komposit CLPR. Keputusan menunjukkan bahawa sifat mekanikal komposit CLPR bagi kelima-lima nisbah mesra alam adalah signifikan kerana nilai-P adalah lebih rendah daripada tahap pemotongan ketara iaitu α = 0.05. Oleh itu, ia menunjukkan bahawa sifat mekanikal untuk lima nisbah mesra alam bagi komposit CLPR mempunyai purata yang berbeza.

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Thank you to the respected person Dr. Iskandar Bin Waini for your unwavering support, direction, and belief in my ability to complete this project. Having him as my supervisor is a blessing because of his positive attitude of providing excellent assistance and direction, even though he was too preoccupied with his affairs to assist me during this project. A debt of gratitude is also owed to Ts. Dr. Khairum Bin Hamzah, my co-supervisor for pointing and providing us with the guides for our framework.

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LIST OF SYMBOLS AND ABBREVIATIONS

CFRP	-	Composite fiber reinforced polymer
D,d	-	Diameter
CNC	-	Computer numerical control
V_{max}	-	Maximum cutting speed
l	-	Length
Wt %	-	Weight percentage
UTM	-	Ultimate Testing Machine
MMC	-	Metal Matrix Composite
CMC	-	Composite Matrix Composite
PMC	-	Polymer Matrix Composite
CLPR	-	Coconut Leaf Polyester Resin
20CL80PR	-	20% of Coconut leaf, and 80% of Polyester resin
40CL60PR	-	40% of Coconut leaf, and 60% of Polyester resin
50CL50PR	-	50% of Coconut leaf, and 50% of Polyester resin
60CL40PR	-	60% of Coconut leaf, and 40% of Polyester resin
80CL20PR	-	80% of Coconut leaf, and 20% of Polyester resin
SS	-	Sum of Squares
df	-	Degrees of Freedom
MS	-	Mean Square

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CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, the most popular new materials for composites are now plastic and ceramics. To break through and grab new markets, composite materials have expanded in volume and number of applications. Rice husk, dried fruit, straw, wheat husk, and hemp fibres are among the natural elements that can be used to generate agricultural waste-reinforced polymer composites for commercial purposes. Bio-based items have an incredible chance to flourish on the planet market. This is due to the fact that natural fibres have a fundamental interest in weight and fiber-matrix adhesion, and there are numerous varieties of natural fibres available, including sisal, eucalyptus grandis pulp, hibiscus cannabinus, ramie bast, kenaf leaves, pineapple leaves, coconut, hemp leaves, sansevieria leaves, vakka, jute, banana, hemp, cotton, ramie, and sugarcane fibres (Majid Ali, 2020).

Natural fiber, which may be produced from leaves, seeds, and grass, is also a renewable resource. Coconut is also abundantly accessible in numerous nations, including Thailand, India, Indonesia, Sri Lanka, Malaysia, and Bangladesh. Natural fiber has recently sparked increased attention and demand in a variety of industries. The biodegradable bio-renewability composite is a particularly appealing feature. Natural fibers are also recognized to have superior mechanical qualities when compared to synthetic fibers. Coconut fibre has the advantages of being a renewable resource and a CO_2 neutral material. Other than that, the fibre is plentiful, non-toxic, biodegradable, light in weight, and low cost and it retains a lot of water and is high in micronutrients (Thyavihalli Girijappa *et al.*, 2019).

Coconut waste now had been become a large amount of waste in Malaysia. According to Rice and Industrial Crops Centre (MARDI), they stated that in years 2007 Malaysia produced 382000 tons of coconut, with 109185 hectares of land dedicated to coconut tree planting. It is possible to recycle and reuse the garbage. The rise in population will increase garbage. Furthermore, there is waste that is difficult to degrade and will remain in the environment. Oil palm, wood, rice, coconut, rubber, and other environmental resources are found in Malaysia. Due to its strong and non-perishable composition, this substance has the potential to replace the major waste material (Sivapragasam, 2018).

The material required for this composite is coconut leaf. Coconut leaf composite is more attractive because of its great strength, small weight, less density, and they are ecological and eco-friendly. Coconut leaf is a common natural filler found in forest nations for example Asian countries like Indonesia, Malaysia, Sri Lanka, Thailand, and India are among the countries involved. Coconut leaves are also easy to obtain, low cost, and easy to process. Coconut plantations occupy a large portion of Malaysia's agricultural area. The operations of the Malaysian coconut industry contribute a little amount to the Malaysian economy witha 0.08% contribution to export revenues in 2006. In this study, composites of coconut leaf were modified to produce panels with different matrix differences and reinforcing materials. Tensile, flexural, and impact tests will be performed as part of this research.

According to Rajesh Kumar *et al.,* (2022), the most appropriate strategy for determining the physical properties of the material as a result of testing is to use mechanical test results such as strength, ductility, strain hardening, modulus of elasticity, and tensile strength. This test involves measuring loads and maintaining consistent tension in coconut fibre specimens. The Universal Testing Machine is set to a tensile speed of 10 mm/min and a distance of 115 mm between the clips. Due to higher fibre weight breakdown, the tensile strength will also increase. In order to obtain more precise results, the study used multiple specimens for each fibre percentage. Since the function of fibre volume and modulus is relative to hardness, fibres that increase composite modulus also increase composite hardness in hardness tests (Kong *et al.*, 2018). Violence is defined as a material's resistance to a variety of permanent changes and penetration by other hard materials, as well as its opposition to such permanent penetration (Aydemir *et al.*, 2019).

1.2 Problem Statement

Malaysia's manufacturing industry has grown in recent years. As a result, the usage of materials in the manufacturing industry to create new goods, as well as in everyday life, will expand. The increased demand for crude aggregate will be fueled by the growing need for recycled materials in the manufacturing industry.

Plants, animals, and geological processes all contribute to the production of natural fibres. Coconut leaf are used as a natural fibre in this investigation. Coconut fibre is one of the most durable natural fibres. When the amount of coconut fibre in a composite grows, however, it reduces the cohesion and ductility. As a result, the research will concentrate on reducing how much resin was needed to remove composite materials in order to solve this problem. In addition, as the fibre weight increases, the tensile strength increases as well. Moreover, an alternative made from environmentally friendly waste is coconut leaf. The majority of Malaysians use coconut in their daily cooking. Coconut leaf are often discarded and burned. While, in India, they have been used to make toys, and they are used to make brooms (Logeswaran et al., 2017) and burnt to ash to make lime. Coconut leaf also has the potential to replace aggregate from waste due to its good for relieving muscular pain and another way to cure the ache is to bathe in the mixture.

1.3 Research Objective

The main aim of this research is to investigate the mechanical properties of coconut leaf reinforced polyester resin. Specifically, the objectives are as follows:

a) To fabricate coconut leaf composite reinforced polyester resin.
b) To study the mechanical properties of coconut leaf reinforced polyester resin.
c) To determine the significant differences on different ratios of the reinforced composites by using the statistical analysis.

1.4 Scope of Research

The scopes in this project are to investigate the mechanical properties of coconut leaf waste-based materials reinforced by polyester resin. This research will divide into four stages. The first stage is the fabrication of the materials by using the hand lay-up technique. While the second stage is cutting the fabricated material into the testing specimen using the CNC router machine. The third stage is the testing of the mechanical properties of the specimen using tensile, flexural, and impact tests. It is very important to get the best result and comparison of previous research. The final stage is the analysis of the results using statistical analysis. Based on the analyzed results of the mechanical properties, we will be obtained the best ratio on coconut leaf reinforced by polyester resin.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of Composite

This chapter summarizes the findings of some different studies on fiber, natural fibers, coconut leaf fiber, and polymer composites. The information acquired from the literature review was used as the basis for investigating the mechanical properties of coconut leaf reinforced with polyester resin. A composite material is a microscopic combination of two or more components classified as a "matrix" or "reinforcement" (ACMA, Nd), with one being a continuous phase and the other being a phase that can't be sustained. Generally, phrases like "ingredients" or "two or more known voters" are used loosely. When high strength and strength composites are mixed with low fibre density, the key advantages are high strength and strength composites. Furthermore, it enables weight savings in the finished item when compared to bulk materials. To solve a better material, (Bharath *et al.*, 2022) defines a composite as "a compound material different from the alloy in that individual components retain their features but are so blended into composites to utilize their features instead of coming short of them."

The shortage of renewable resources is a concern for composite materials developed from natural resources. Natural composite materials, as a result, have suffered substantial disadvantages in recent years as a result of increased environmental awareness. Low cost, high specific strength, lightweight, and biodegradable humidity are some of the key advantages of natural fibres over synthetic fibres. Individual phase characteristics, volume fraction, and connectivity are extremely essential in composites. In the powder business, polymer composite is made of two or more natural components along with different physics and chemical properties that work together to make a stronger material than the original. Coconut, bamboo, and a variety of other natural materials can also be used to make composites. The fibres are protected by the matrix against external and environmental degradation. The fibre-reinforced composites are used to improve the process, appearance, and ultimate result (Chandramohan and Presin Kumar 2018).

2.1.1 Need for Composite

Several materials require enhancements in order to get desired results. It's tough to discover a single material that has all of the desired qualities. Consider a material that requires a high fatigue life but does not require a high cost. The core pieces of a composite maintain their individual identities while working together to give a variety of benefits (ACMA, n.d.). The advantages of the composite are shown in Table 2.1.

Table 2.1: The Advantages of Composites

Advantages of Composite	
➢ Strength ➢ Stiffness ➢ Toughness ➢ High resistance to corrosion ➢ Extremely durable ➢ Chemical resistance that is exceptional	➢ Weight-lost ➢ A long life expectancy ➢ Thermal& electrical insulation or conductivity ➢ Reduced cost ➢ Energy dissipation

The lists of desirable features in Table 2.1 are not exhaustive. The most significant feature of composite materials is that their properties are satisfied, i.e., the required attributes can be designed.

2.1.2 Type of Composite

Metal Matrix Composite (MMC), Composite Matrix Composite (CMC), and Polymer Matrix Composite (PMC) are three types of composite matrix materials that can be classed based on their composite matrix (PMC). PMC is the optimum type for matrix composites. In fact, for many mechanical properties' structures, the polymer is insufficient. As a result, in comparison to metals and ceramics, their strength and stiffness are low. There are two forms of polymer composites: fibre reinforced polymer (FRP) and particle-reinforced polymer (PRP) (Kai Bin Liew *et al.*, 2021).

Metal Matrix Composites with great strength in the cross-section, resistance to corrosion, and specific modulus have good qualities on monolithic metal (MMC). MMC is commonly utilized in covers, tubes, cables, heat exchangers, and structural components because of its property. The high density of MMC means it has inferior mechanical qualities to polymer matrix composites, and its production requires a lot of energy.

Ceramic Matrix Composites (CMC) or ceramic fibres are noted for their temperature resilience. Ceramic fibre comes in two forms: alumina and silicon carbide, and it excels in applications that require extreme temperatures or are vulnerable to environmental factors. Because of its delicate nature, ceramic has weak characteristics in tension and shear, hence most applications use it as particle reinforcement (Poornesh *et al.*, 2022). CMC is a ceramic material with short fibres or moustaches formed of silicon carbide and boron nitride that is utilised in extremely high-temperature applications.

To make particle composites stronger, particles of one or more materials are suspended in a matrix of another component. When a matrix module is added and the matrix's ductility is reduced, particle kinds will be considered. For reinforcing particles, ceramics and glass are employed. The ordinary fibre reinforced composite is made up of a mixture of fibre and composite, and it uses two types of fibres such as short and long. It is attributed to fibre-reinforced composites. One element is incorporated into a matrix with another substance that proves to be extremely powerful. As a result, composite fibre composites will bear weights in their longitudinal orientation.

2.2 Type of Matrix Composite

Composite is a term that refers to a material that combines fibre reinforcement with a resin matrix (Fibermax Composites, n.d.). The matrix or resin system can hold everything together and convey mechanical loads to the entire structure via fibre. Furthermore, a structure merged or the material can be protected against abrasion and corrosion when it is bonded with resins, contaminants, other environmental conditions, and rough handling, as well as extend the life of the structure of the material. The resin system is available in a variety of chemical families, each of which is created and commissioned to serve industries with specific benefits such as cost, structural performance, resistance to various causes, and legal compliance. Polyester (Orto phthalic and polyester) are the only resins that are appropriate. The resin system is available in a variety of chemical families, each of which is created and commissioned to service businesses that require certain characteristics such as cost, the performance of the structure, resistance to various variables, and legal compliance. Polyester (Orto phthalic and isophthalic), vinyl ester, epoxy, and phenolic resins are the only ones that can be used. Carbon and ceramics are commonly utilized in the form of thermosets for high-temperature composite matrices. Thermosets like epoxy and polysulfide, as well as thermoplastics like ketone polyether and polyimide polyether, are pioneers in research and industrial applications because of their great strength and performance. Nano-composites, which can be produced for a wide range of applications and have a high aspect ratio and improved electrical, mechanical, and thermal qualities (Chauhan *et al.*, 2018).

We discovered that there are two broad kinds of resins that we may term polymer materials: thermosets and thermoplastics, based on our research. Polymer is used to make these resins. Furthermore, thermoset resins were used to create the best composites. The thermoset resin is "cured" with catalysts, heat, or a combination of both when used to make finished objects. A solid thermoset resin cannot be returned to its original liquid state after healing. Polyester, vinyl ester, epoxy, and polyurethane are common thermosets. Tables 2.2 and 2.3 highlight the benefits and drawbacks of thermoplastic and thermoset resins, respectively.

Table 2.2: Advantages and Disadvantages of Thermoplastic

Thermoplastic Resin	
Advantage	Disadvantage
• Resistant to high impacts • Highly recyclable • Reshaping capabilities • Chemical resistant • Hard crystalline	• Expensive • Can melt if heated

Table 2.3: Advantages and Disadvantages of Thermoset

Thermoset Resin	
Advantage	Disadvantage
• More resistant to extreme heat • Highly flexible design • Capabilities for thick and thin walls • Excellent dimensional stability • Cost-effective	• Cannot be recycled • More difficult to surface finish • Cannot be re-molded or re-shaped

2.2.1 Thermoplastic

Thermoplastic polymer resins are commonplace, and they interact with thermoplastic resins frequently. Most thermoplastic resins are unreinforced, which means they are molded into shapes with no reinforcing to provide strength. The following are current thermoplastic resins and some goods made with them: Polypropylene - Packaging containers, Polycarbonate - Safety glass lenses, PBT - Children's Toys, Vinyl - Window frames, Polyethylene - Grocery bags, PVC - Piping, PEI - Airplane armrests, and Nylon – Footwear.

Strengthening thermoplastic products is done with short-term fibres. Thermoplastic goods are strengthened using short-term fibres. Fiberglass and carbon fibre are the best reinforcing materials. In fibreglass laminations, thermosetting polyester resins are frequently utilised as bonding agents. Compared to competitive epoxy resins, polyester resins are less expensive. These resins start a chemical reaction that results in curing by using hardeners.

In general, composite FRP refers to the utilization of fibre or fibre reinforcement with a length of 1/4" or larger. Continuous fibres and thermoplastic resins were combined to create a composite product structure. The several advantages and disadvantages of thermoplastic composites and thermosets are numerous. When starch thermoplastic is not used, the Eucalyptus urograndis pulp used as a reinforcement for the canopy thermoplastic has a high tensile, with 100% and more than 50% in modulus, according to Chuhan *et al.*, (2018).

2.2.2 Thermoset

Composite of Combined Polymers Traditional Fibre Composite, or FRP Composite for short, is made of thermoset resin as a matrix. On this composite mechanical, a strong structural fibre is held in this matrix. The following are some of the most common thermoset resins: Polyester resins, and Vinyl Ester Resin.

2.3 Fibre

Natural and synthetic fibres are the two forms of fibre that can be found. Figure 2.1 depicts this categorization.

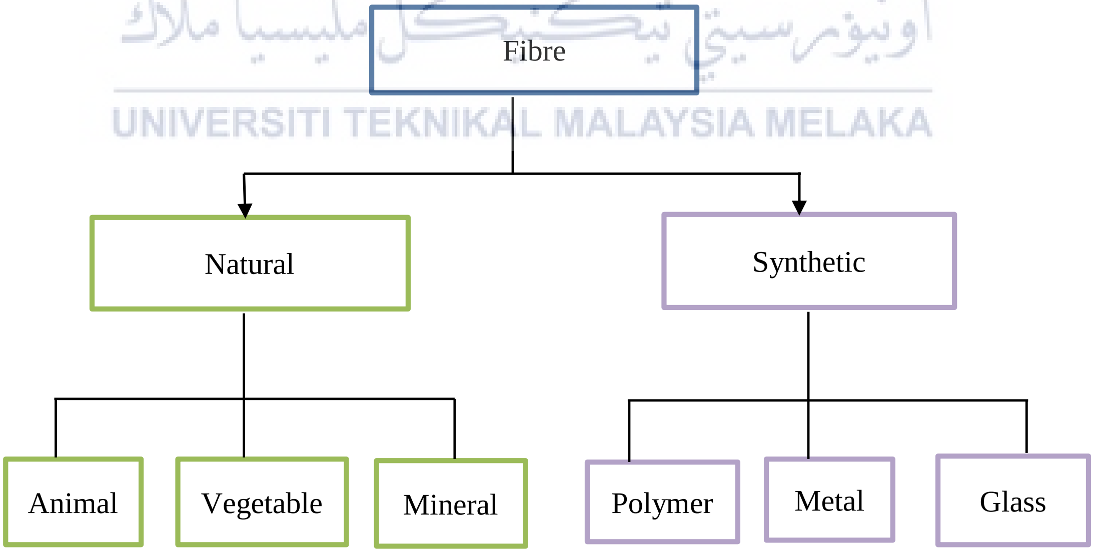


Figure 2.1: The classification of fibres is based on natural and synthetic fibres

Natural fibres include mineral, vegetable, and animal fibres. In terms of chemical composition, the plant and animal kingdoms are polymeric, whereas minerals are crystalline ceramics. Natural fibres are made up of many different chemical and physical components. Synthetic fibres include polymer, metal, and glass.

Proteins can be found in animal fibres like silk, wool, mohair, and alpaca. Asbestos, for example, is a mineral fibre. Glass wool and quartz are examples of glass fibres, whereas metal fibres include aluminium, brass, steel, and other metals (Natrayan *et al.*, 2021).

In the form of short filament threads, vegetable fibres such as sisal, jute, and coconut have been employed as reinforcement of cementitious matrices. Tension softening and low tensile strength was seen in short filament shape composites, resulting in products that were better suited to non-structural applications. Fibres from wood, bamboo, and sisal pulp have also been used as reinforcement (Roma *et al.*, 2018).

2.4 Natural Fibre

Natural fibres are classified into six categories: bast, leaf, seed, core, grass/reeds, and other natural fibres. For natural fibres, the botanical type is the most prevalent classification. Plants can create a variety of fibres. Fruit and stem fibres can be found in plants like agave, coconut, and oil palm. Both bast and core fibres are found in jute, flax, hemp, and kenaf (Rowell, 2018).

Table 2.4 displays a more detailed list of natural fibre classifications, showing that coconut fibre (coir) belongs to the seed category. Fibres, pods, husks, fruits, and hulls are the five types of seed fibre. The coconut fibre is classified as husk in this categorization.

Table 2.4: Six general types of natural fibres (Rowell, 2018).

Bast	**Leaf**	**Seed**				**Core**	**Grass/reeds**	**Other**
		Fibres	**Husk**	**Fruit**	**Hulls**	**Kenaf**		
Hemp	Pineapple	Cotton	Coir	Oil palm	Rice	Jute	Wheat	Wood
Ramie	Sisal				Oat	Hemp	Oat	Roots
Flax	Agava				Wheat	Flax	Barley	Galmni
Kenaf	Henequen				Rye		Rice	
Jute	Curaua						Bamboo	
Mesta	Banana						Bagasse	
Urena	Abaca						Corn	
Roselle	Palm						Rape	
	Cabuja						Rye	
	Albardine						Esparto	
	Raphia						Sabai	
							Canary	
							Grass	

Mathur (2019) examined the creation of construction materials based on local resources, with a focus on natural fibre composites. In order to overcome their well-known moisture absorption concerns, the potential of sisal and jute fibres as reinforcements has been intensively investigated. Different humidity, hydrothermal, and weathering conditions were used to test the performance of polymer composites produced from these natural fibres and unsaturated polyester/epoxy resin. Laminates/panels, doors, roofing sheets, shuttering, and dough moulding compounds are among the composite items that have been developed. According to existing Indian standard specifications, the suitability of this product as an alternative material is evaluated. Mathur discovered in this study that natural fibre composites have a lot of potential as alternative materials, particularly as wood substitutes, and that they are especially relevant to develop countries like India because of their low cost, energy efficiency, and applications as substitute materials.

Natural fibres have similar specific tensile strengths to glass fibres, according to Staiger and Tucker (2018), carbon or aramid fibres, however, are not competitive. The potential of sisal and jute fibres as reinforcements has been thoroughly researched in order to overcome their well-known moisture absorption issues.

2.5 Work Material

"Work material" refers to materials, instruments, equipment, parts, installations, facilities, supplies, and resources required for the job execution but not to be included in or consumed during engineering manufacturing. This project will use a variety of items.

2.5.1 Coconut leaf

Due to the potential nature of natural features, eco-friendly materials such as biocomposites have been found to be in constant high demand in recent years. Biocomposites are created from recycled fibres and are derived from plants. In many regions of the world, coconut leaf is one of the most affordable materials. The Philippines and India are the world's top coconut producers, followed by Indonesia and the Philippines. Coconut leaf behaviour varies depending on geography, season, and species. The coconut leaf's cellulose and lignin components contribute to its strength. The mechanical behaviour of reinforced sandy soil in tri-axial circumstances has been studied in the previous decade. A series of tri-axial tests with varied confining pressures were done to assess the effect of gypsum cementation on gravelly sandy soils. The findings showed that when confining pressure and friction angles increase, so does soil brittleness, but cohesiveness increases as gypsum content increases. (Jishnu *et al.*, 2019).

The tree of life, Cocas Nucifera, is a monocotyledon with an unbranched trunk. A coconut tree can grow to be 30 metres tall and generate 17 fronds every year. According to Harries and Clement (2019), the exact origin of the coconut palm is still unknown, however, research based on molecular data and fossils indicates that it is most likely from Southeast

Asia. Each part of the coconut palm has a significant commercial value. Coconut meat is used in the production of coconut oil and vinegar. Charcoal and activated carbon are made from the shell. The husks, trunk, and leaves can all be useful in civil engineering applications. Coir, a very flexible substance used for ground improvement, is effectively made from coconut husks. Even before the age of 50, coconut trunks were utilised as pile foundations to support weak soil and prevent differential settling. The midrib of the coconut leaflet is used to produce brooms, and it is a common thatching material.

In this research, coconut leaf fibres derived from natural wastes are used as reinforcement in polyester matrices. The purpose of this material was to investigate the mechanical properties of coconut leaf waste-based materials reinforced by polyester resin. Figure 2.2, and 2.3 illustrates the coconut leaf and coconut leaf powder.

Figure 2.2 Coconut Leaf

Figure 2.3 Coconut Leaf powder

2.5.2 Properties of Coconut Leaf

The coconut palm (Cocos nucifera Linn.) is an evaluable tropical resource, that supplies food, energy, and many economically viable products. In tropical countries like Malaysia, Indonesia, Thailand, Sri Lanka, and India traditionally eco-friendly palm leaf woven houses, umbrellas, baskets, and separating screens are common. Natural fibres have some advantages over manmade fibres, including low cost, lightweight, renewable character, high specific strength and modulus, and availability in a variety of forms throughout the world (Rajulu *et al.*, 2021).

According to Uswatun Hasanah *et al.*, (2020), the physical and chemical properties of young coconut leaves were expected to be the basis for the development of young coconut leaves as an environmentally friendly packaging material. The results showed that fresh and steamed young coconut leaf colour was greenish-yellow and brownish-yellow. Coconut is a plant with several uses. Coconut has been utilized as firewood, drink, edible oil, fibre, animal feed, and building materials in addition to being a food source. Some coconut by-products have been explored as potential precursors for the synthesis of activated carbons, including husks, shells, mesocarp, frond, and coir (Etim *et al.*, 2019). Its leaves, on the other hand, have minimal utility. Normally, the leaves are grown solely for handcraft and decoration. Although the literature on the superiority of coconut leaves structure is lacking, agriculture waste components such as hemicellulose, lignin, lipid, protein, simple sugar, water, hydrocarbon, and starch all contain functional groups with sorption potential (Bhatnagar *et al.*, 2020).

According to Jishnu *et al.,* (2019), cellulose fibril and amorphous components (lignin and hemicellulose) determine the strength of natural fibres in coconut leaflets. When natural fibre comes into touch with the soil-matrix, which absorbs water and accelerates biodegradation and fibre swelling, it faces a serious constraint. This can have a negative impact on fibre reinforcement mechanisms. Carbon dioxide and water were generated together with carbon residue during aerobic decomposition. However, methane is produced together with the carbon residue in anaerobic decomposition.

2.5.3 Application of Coconut Fibre

In the construction industry, some building components like ceilings, door frames, door shutters, and roofing sheets are made from sisal, jute, coir, and other natural fibres. Bagasse is now used to make particle boards in some locations across the world. In Thailand, coconut fibre is also used to make Thai hardwood, which has better qualities than Japanese hardwood. Furthermore, bio-waste fibres are used to create better furniture, such as medium density fiberboard (MDF), which is widely used in various regions of the world for various types of furniture (O.S.I. Fayomi *et al.*, 2020).

Ayrilmis Nadir *et al.*, (2018) claimed that coconut fiber reinforced polymer composites were developed for industrial and socio-economic applications such as automotive interiors, panelling, and roofing as building materials, storage tanks, and packing material, helmets, projector covers, voltage stabilizer covers, and so on. Many industrial organizations are looking for innovative composite materials with specified mechanical, chemical, and dynamic qualities, as well as being environmentally benign. A proposal for coconut leaf midrib compounding with resin for composite material has been proposed in the search for such new material. It is relatively water-resistant and resistant to microbial deterioration and saltwater damage.

2.6 Cutting Process Machine

The project will carry out the cutting of fabricated materials into test specimens using the CNC router machine. In addition, the specimens are cut according to a certain size range, certain parameters, and with the appropriate tool eye speed. Therefore, this literature review will be included researchers who have used this machine as a tool to cut specimens.

2.6.1 CNC Router Machine

A computer-controlled router can cut, engrave, and carve a variety of materials, including wood, composites, aluminium, steel, plastics, and foams. The cutter on a CNC router can be put in any location while being guided by three axes of motion. That is, it may move the cutter left-right, from-to, and up-down at the same time. In terms of concept, a CNC router is similar to a CNC milling machine (Prashil et al. 2019).

Researchers studied the design and development of a portable 3-axis CNC router machine based on a microcontroller, which may be utilized to lower the cost and complexity of large-scale engraving equipment. On wood, acrylic, and PCB materials, CNC router machines were used for engraving, cutting, reaming, marking, drilling, and milling. In his research, CNC machines were utilized to cut, carve, and brand wood (Prashil et al. 2019).

Next, researchers investigated the influence of multi-wall carbon nanotubes on the dynamic characteristics of woven composites made of Kevlar or carbon-polyester fibres. Test samples were collected using composites made on an ASTM-compliant CNC machine (Aubad et al. 2020). A CNC router was used to cut specimens with dimensions of 250 mm x 25 mm x 4 mm for tensile testing (Righetti et al. 2017).

Balcıoğlu and Yalçın (2020) investigated the fracture stiffness of knitted laminate composites using test samples sliced with a CNC router machine at a thickness of 3 mm. According to Webo *et al.,* (2020) the tensile strength and flexural strength parameters of untreated and treated sisal fibre-epoxy resin composites were investigated. Flexural strength and stiffness were measured using a three-point bending test. The specimen, which was 48 mm long, 3 mm thick, and 12.7 mm wide, was cut with a CNC router machine. Figure 2.4 depicts the CNC router machine.

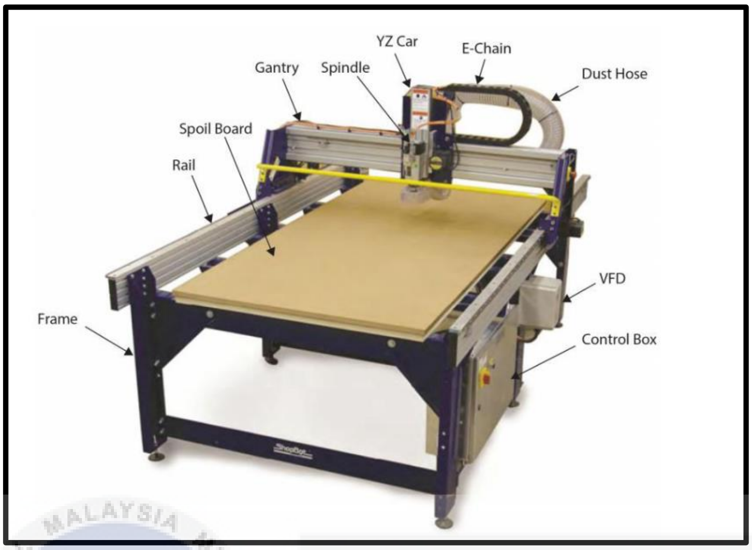


Figure 2.4 CNC Router Machine

The fundamental difference between CNC milling and CNC router is the material that may be machined. CNC routers are less expensive than CNC mills and have a smaller body. They can only work with wood, composites, and soft metals like aluminium. The machine is mainly divided into two, one is the control panel with X, Y, and Z movement and another is the main spindle which is controlled by the Variable Frequency Drive (VFD). When we utilize the bed, we can see the sacrificial layer on the top of it. Hand clamps or nails can be used to secure the workpiece here. There are other options, such as wedges or vacuum suction, but we'll only use nails and clamps here.

2.6.2 Cutting parameters

a. **Chip Load:** It is the theoretical length of material that is fed into each cutting edge as it moves through the work material.

- Chip Load = Feed Rate (inches per minute) / (RPM x number of flutes)

b. **Depth of cut:** It is the depth at which the tool removes the material in one pass. Maximum depth is the diameter of the tool, so you cannot have the depth of cut more than the diameter of the tool. A higher depth of cut may decrease the time but may break the tool or reduce the tool life.

c. **Spindle speed:** It is the speed of the spindle which is given in RPM, it depends upon the material we are cutting and the number of flutes. Different Speeds than calculated may reduce toolpath, or induce very fatal fire.

d. **Feed rate:** It is the lateral speed of the tool while cutting the job. Very less speed increases the job time and high speed will have a bad impact on tool life or even break the tool. So optimum value should be chosen. perfect cut.

The above parameters should be chosen wisely. If the parameters are not properly chosen, the sound the tools make while going through can be noted. In the worst condition, the chips might catch fire which when passes through the duct collector cannot be controlled.

According to Patel and Patni (2019), CNC router machine operation parameters like tool speed, tool feed, and depth cut were investigated. The goal of the experiment was to cut the composite. The level machine parameters are shown in Table 2.5.

Table 2.5 The Parameter of Level Machine (Patel and Patni 2019)

	Level		
Factor	1	2	3
Spindle speed (rpm)	8000	10000	12000
Feed (mm/min)	1000	2000	3000
Depth of cut (mm)	0.75	1	1.5

2.7 Mechanical Testing

Every design and manufacturing process must include mechanical testing. When it comes to specifying material attributes or providing certification for finished products, safety is crucial. Testing is also important for assuring a cost-effective design as well as technological advancement and supremacy. This project will be carried out by testing the mechanical properties of the specimen using tensile, flexural, and impact tests. It's crucial to get the best possible result and compare the previous study.

2.7.1 Tensile Test

The material is cut into specimens with dimensions 260mm x 24mm x 5mm as shown in Figure 2.5 (a) & (b) tensile testing as per ASTM 3039/D 3039M requirements (as shown in Figure 2.5 (a)), see Vinod V. Rampur *et al.,* (2020). The specimen's tensile strength is determined with a digitalized UTM tensile tester with a maximum capacity of 10kN. An electronic tensiometer was used to evaluate the samples at a crosshead speed of 2mm/min (UTM). The UTM had enough sensors to record all of the changing parameters during the test. Fabricated objects (as indicated in figure 2.5 (b)) will be placed between the grippers in the UTM's moving and stable jaws and progressively dragged apart until the object breaks. The tensile behavior of the material evaluated in the UTM is determined by the tensile test, which in this case is the tensile strength of composites constructed of coconut and wood apple shell powder.

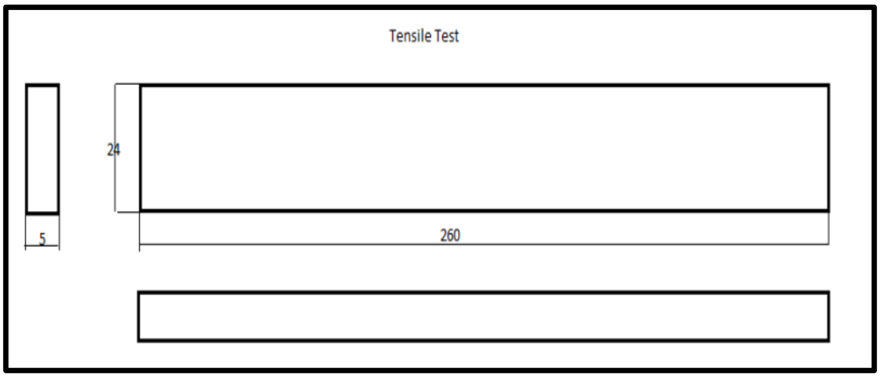


Figure 2.5 (a). Tensile test specimen 260 x 24 x 5 mm (Vinod V. Rampur *et al.*, (2020).

Figure 2.5 (b). Fabricated specimens as per dimensions (Vinod V. Rampur *et al.*, (2020).

When the percentage of coconut shell powder added to the Wood apple shell powder is increased, there is an increase in tensile stress for all of the cases evaluated. It was first determined that the tensile strength of 0% coconut shell powder and 30% wood apple shell powder was growing. The percentage of wood apple shell powder then dropped as the percentage of coconut shell powder grew. When the percentage of coconut shell powder climbed and the percentage of wood apple shell powder fell, the values were found to be constantly increasing. The tensile strength of coconut shell powder and wood apple shell powder composites containing 15% coconut shell powder and wood apple shell powder reached a maximum of 18.12 N/mm2. (Vinod V. Rampur *et al.*, 2020).

Furthermore, Sindhu and Chouhan (2018) investigated the mechanical properties of a reinforced epoxy composite manufactured from scrap coconut shells. For determining the strength of a specimen, they used tensile and bending tests. The specimen was made by mixing 5%, 10%, and 20% of coconut shell weight. The composite made from 20% carburized coconut charcoal particle-packed epoxy composite has the highest tensile and bending strength. Table 2.6 presents the tensile testing parameter in three volumes. At 20% of the volume of coconut shell powder, tensile strength is highest.

Table 2.6 Parameter of tensile testing (Sindhu and Chouhan 2018)

The volume of Coconut Shell Powder (%)	Ultimate Load (N)	Tensile Strength (MPa)
5	5450	35.4
10	5560	36.12
20	6940	45.08

2.7.2 Flexural Test (3-point Bending)

Bend testing is used in composites to assess the stiffness and flexural strength of a solid laminate or sandwich construction. In a flexural test, the specimen is loaded horizontally in a three-point or four-point loading configuration. Furthermore, the stress in a material just before it yields in a flexure test is known as flexural strength, which is also known as the modulus of ruptures., see Vinod V. Rampur *et al.*, (2020). Figure 2.6 (a) & (b) shows flexural specimens prepared according to ASTM 790/790M standards. The most common test is the transverse bending test, which involves bending a specimen with a circular or rectangular cross-section until it fractures or yields using a three-point flexural test procedure. The maximum stress experienced within the material at the moment of yield is represented by the flexural strength.

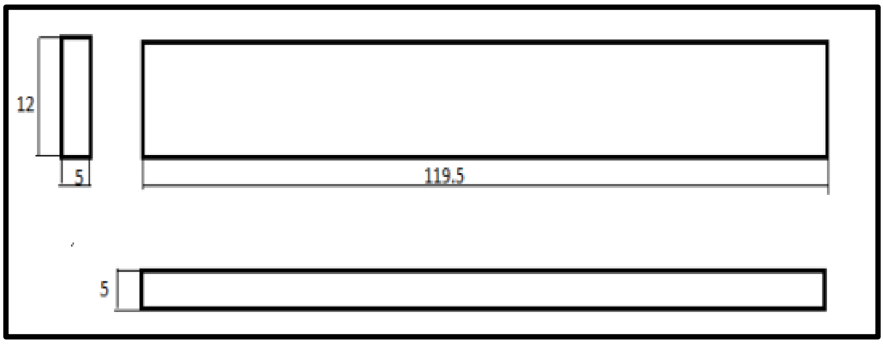


Figure 2.6 (a). Flexural Test specimen with dimension of 119.5 x 12 x 5 mm (Vinod V. Rampur *et al.*, 2020).

Figure 2.6 (b). Fabricated Flexural specimens as per standards (Vinod V. Rampur *et al.*, 2020).

2.7.3 Impact Test

The Charpy test is used to find out how much energy composites have when they hit each other and to investigate the specimen's shock resistance. The joules were used to measure the amount of energy received by the specimen before it failed. Shock resistance is measured in joules. ASTMA370 specimens were used in this technique (55 x 10 x 10 mm). The brittle nature of the coconut fibre reinforced composites contributed to the lower impact test results. The epoxy E-glass composite has exceptional impact strength. When each specimen is subjected to a severe impact hit from a pendulum, energy is absorbed and cracks occur. The break is frequently transmitted through the composite's fibre and resin. As a result, energy absorption will be considered when a crack travels through the composite. Glass fibre reinforced composites are discovered to have a high breaking load (5.8 KN). Epoxy E-glass fibre reinforced composite has a breaking load that is 1.93 times that of epoxy coconut fibre reinforced composite and 2.07 times that of polyester coconut fibre reinforced composite (R.d. Hemanth *et al.*, 2017).

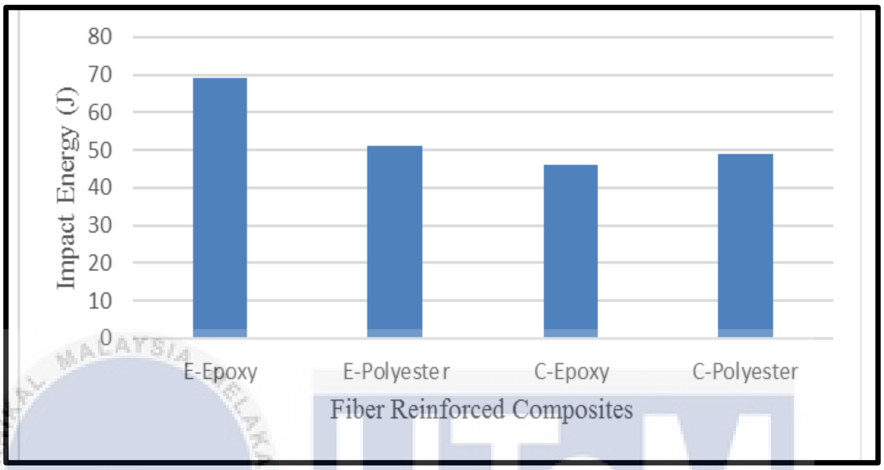


Figure 2.7: Impact Test Results for E-Glass & Coconut Fiber Reinforced Polymer Matrices (R.d. Hemanth *et al.*, 2017)

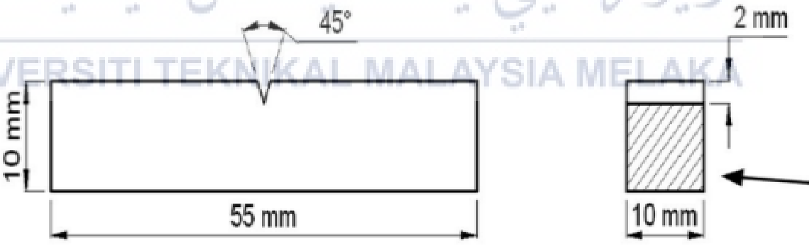


Figure 2.8 Size of specimen according to ASTM A370 (R.d. Hemanth *et al.*, 2017)

2.7.4 The Analysis of the results using Statistical Analysis (ANOVA)

ANOVA is a statistical approach for determining if the means of two or more groups are substantially different. ANOVA compares the means of several samples to see how one or more variables influence the outcome. According to Bankoti *et al.*, (2017), optimization of tensile stress and flexural stress of epoxy-based walnut reinforced composite was done by using the Taguchi method. At the 95% confidence level, the filler content in weight percent and loading speed had a significant impact on the ANOVA for tensile stress values. Tensile stress is enhanced by increasing loading speed, and the optimal tensile stress value is attained when the filler content is 10% and the loading speed is increased. However, in the flexural test, both the filler weight percent and the loading speed have a significant impact on the flexural stress value at the 95% confidence interval, flexural strength reaches its maximum at 10% filler content, after which it begins to decline up to 25% filler content. In addition, as loading speed increases, flexural strength increases. Tables 2.7 and 2.8 below show the ANOVA table for tensile stress and flexural stress values.

Table 2.7 ANOVA table for tensile stress (Bankoti *et al.*, 2017)

Source	DF	Seq (SS)	Contribution	Adj (SS)	Adj (MS)	F-Value	P-Value
A (percentage filler wt.)	5	308.5	75.90%	308.5	61.71	29.34	0
Loading Speed	2	76.91	18.92%	76.91	38.46	18.28	0
Error	10	21.03	5.17%	21.03	2.103		
Total	17	406.5	100.00%				

Table 2.8 ANOVA table for flexural stress (Bankoti *et al.*, 2017)

Source	DF	Seq (SS)	Contribution	Adj (SS)	Adj (MS)	F-Value	P-Value
A (percentage filler wt.)	5	1004	62.80%	1004	200.8	57.91	0
Loading Speed	2	560	35.04%	560	280	80.77	0
Error	10	34.67	2.17%	34.67	3.467		
Total	17	1598	100.00%				

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter provides detailed information on the procedures or strategies used to find, select, and analyze data about this issue. The methodology part of this chapter allows the reader to critically evaluate the overall process and reliability. The process flow is used in this research to satisfy the current task objective. To meet the present work objective, the process flow is used by this researcher. This research will divide into four stages. The first stage is the fabrication of the materials by using the hand lay-up technique. While the second stage is cutting the fabricated material into the testing specimen using the CNC router machine. The third stage is the testing of the mechanical properties of the specimen using tensile, flexural, and impact tests. It is critical to obtain the finest possible outcome and to compare past research. The final stage is the analysis of the results using statistical analysis. Based on the analyzed results of the mechanical properties, we will be obtained the best ratio on coconut leaf reinforced by polyester resin. Finally, the experimental detail had been defined in this chapter.

3.2 Project Experiment Process

In this project, Table 3.1 shows a block diagram for parameter analysis affecting the cutting process with two different machines. There is one type of machinery is employed to cut the material in this project. A substance of such relevance must be prepared before the experiment. Fabrication materials were coconut leaf and polyester resin.

To cut the coconut leaf, a CNC router machine will be needed. The input parameters are employed to define the feed rate and thickness of the experimental specimen. The outcome parameters of the cutting method will be analyzed once the cutting process is completed to obtain the result. The material will be cut into 120mm × 20mm squares. The tensile strength of the material was then determined using testing equipment.

Table 3.1 Analysis Parameter Effect of Cutting Process

Machine	**Process**	**Input Parameter**	**Output Parameter**
CNC router	Cutting Process	Specimen Thickness	Surface Roughness
		Feed Rate	Heat Effected Zone

3.2.1 Process Flowchart

The flowchart depicts a procedure in which the steps are carried out sequentially. A flow chart is a graph that shows how a workflow or process works. Flowcharts are also a visual representation of algorithms and job-related procedures. The stages are represented as various types of boxes on the flow chart, with the boxes connected to the arrows. This diagram represents a hypothetical solution to a problem. Flowcharts are used to plan and document simple system procedures. A flow chart can help you understand each step of the process and how it's done. From the beginning to the finish of the process, Figure 3.1 depicts the flow.

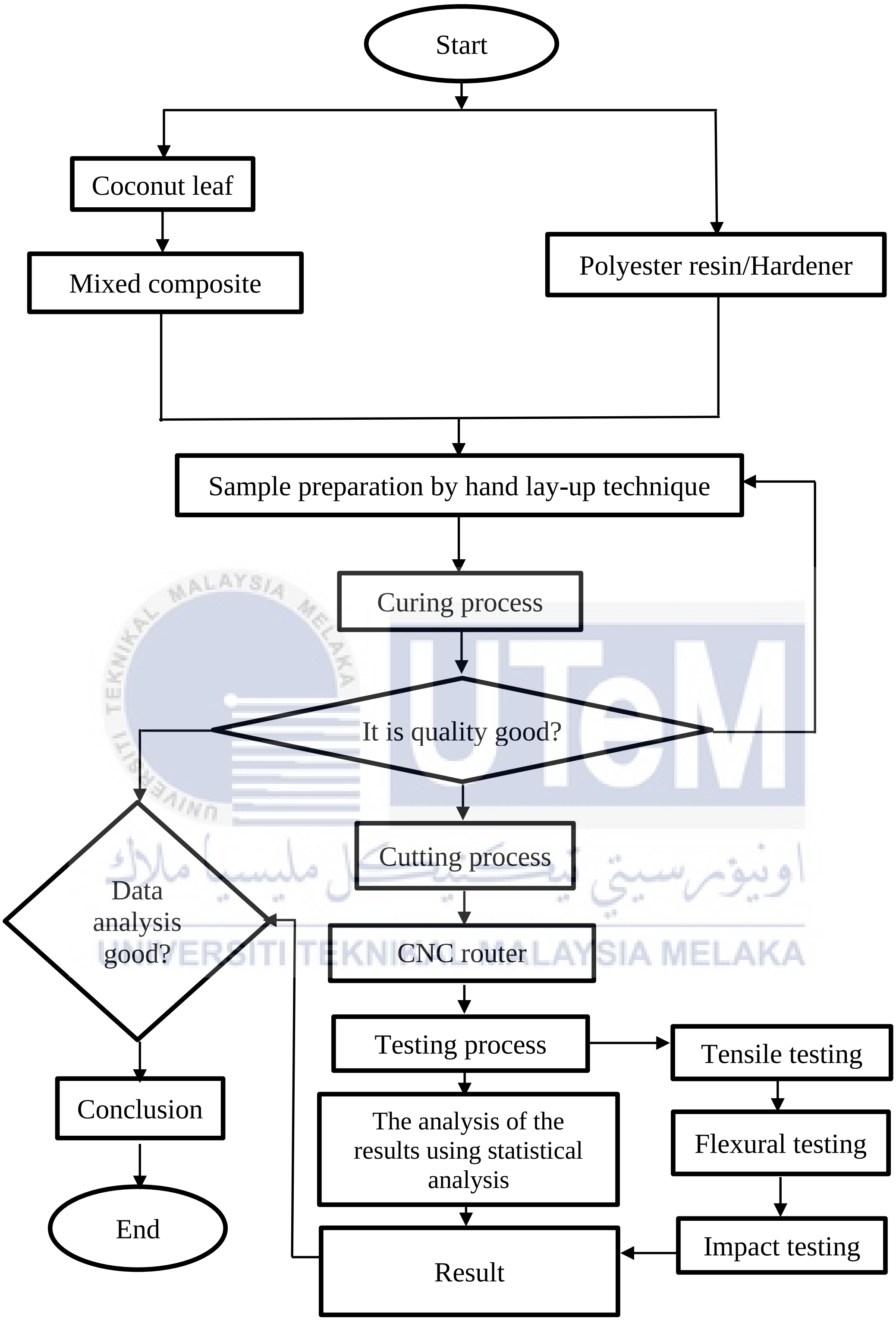


Figure 3.1 Process Flowchart

The flow chart processes represent a workflow that was completed. The procedure is depicted in Figure 3.1 from the beginning to the finish of the study process. First and foremost, the experimental study technique will use polyester resin and hardener to build the specimen, which is a coconut leaf with sandwich lamination, before cutting it to a specific size. When the materials are perfect, the cutting procedure can begin.

Secondly, the CNC router machine is used in the cutting procedure on the specimen. When the specimen is ready to be created, it will be sliced with these machines. The specimen will be cut by a CNC router machine, and the size of the specimen will be divided into three sections tensile testing, flexural testing, and impact testing. The tensile testing dimensions are 120mm length x 20mm width x 3mm thickness according to ASTM D3039 and the dimensions of flexural testing are 120mm length x 20mm width x 3mm thickness according to ASTM D790-07. While, for the impact testing dimensions are 55mm length x 12.5mm width x 10mm thickness according to ASTM E23. Next, after executing the cutting operation on the specimen, gather and evaluate data. If the data gathered is insufficient, the specimen will be sliced and data were taken in order to obtain excellent findings.

3.3 Design of Material Specimen

The specimen dimensions will be 280mm length x 180mm width based on Figure 3.2. Following the development of the specimen, it will be cut to a size of 120mm length x 20mm width for the tensile, and flexural tests. For the impact test, the specimen size will be cut to a size of 55mm length x 12.5mm width. These specimens are fashioned to meet test standards so that better material qualities can be identified after cutting. Specimens are also available in two different thicknesses which are 3mm (tensile and flexural test), and 10mm (impact test). Figure 3.2 shows the dimensional design of specimens for tensile and flexural testing, while Figure 3.3 shows the dimensional design of specimens for impact testing.

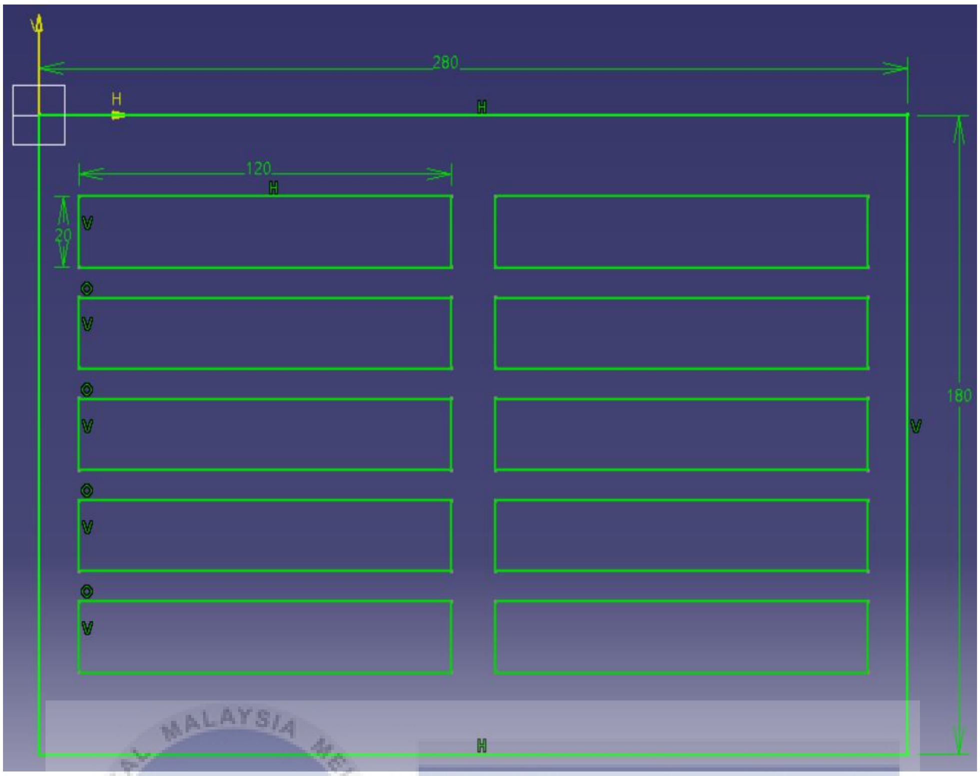


Figure 3.2 The dimensional design of specimens for tensile and flexural testing

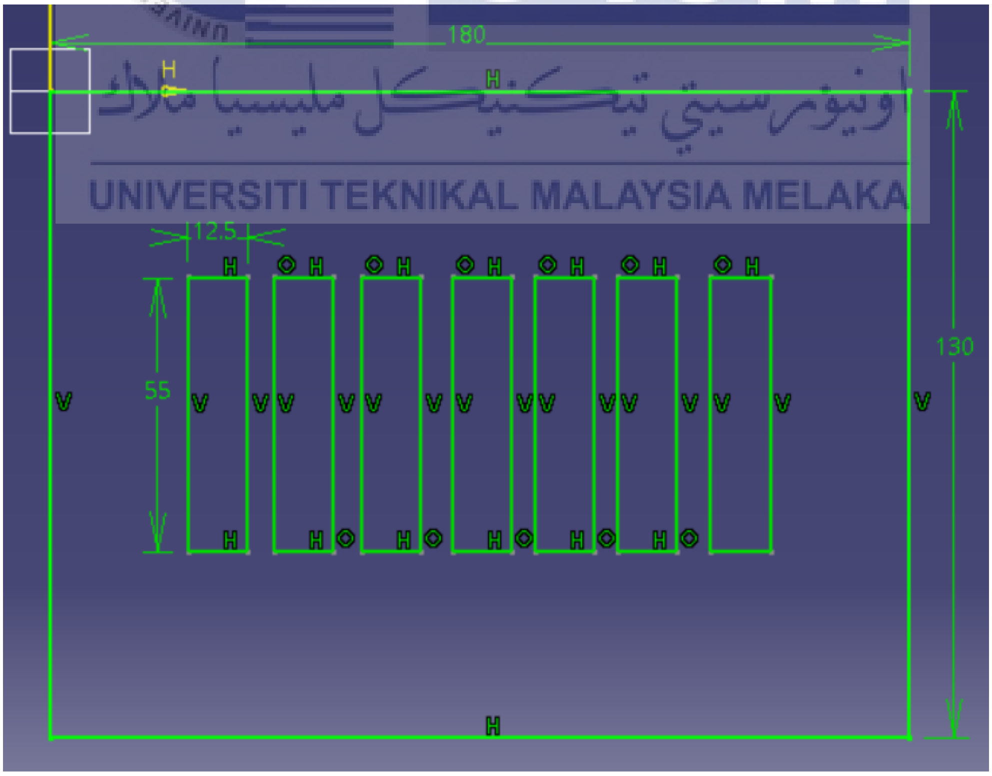


Figure 3.3 The dimensional design of specimens for impact testing

3.4 Experimental Procedure

The experimental method used in this study is a step-by-step strategy for each stream. These procedures are required for the processes and operations to be completed correctly. Each approach necessitates the presence of a focus point to provide good and precise outcomes. Following that, this part will look at numerous phases, including CNC router cutting. Tensile testing, flexural testing, and impact testing were among the procedures employed.

3.4.1 Fabricate Material

In the first instance, the coconut leaf is harvested by hand from coconut trees. The coconut leaf should be removed from the midribs before proceeding to the next process which is clean with tap water. Then it is dried for a few days in sunlight to remove all moisture contents present in the coconut leaf. After the coconut leaf has been fully dried, the coconut leaf is then cut into small pieces using scissors or another cutting machine so that they are easy to crush using a crusher machine. Once done, store the leaf powder that has been blended near a suitable container to avoid contact with water. After the coconut leaf change into powder, take the coconut leaf powder according to the thickness of the weight. Sandwiches manufactured with reinforced material made of polyester resin and hardener contain a certain amount of coconut leaf powder. Then left at room temperature for 2 days or 48 hours. Figure 3.4 shows the coconut leaf powder that have been crusher. The average size is randomly use to produce the composites.

Figure 3.4 The coconut leaf powder

Table 3.2 Parameter of composite ratio

Abbreviations	Coconut Leaf Powder (%)	Weight (g)	Polyester resin (%)	Weight (g)
20CL80PR	20	6	80	226
40CL60PR	40	15	60	205
50CL50PR	50	23	50	197
60CL40PR	60	28	40	192
80CL20PR	80	33	20	187

Next, the material for mold is made from silicone. There are 2 different types of mold used for this experiment. The mold for tensile and flexural testing with the dimensions size of 280mm length x 180mm width. While the dimensions of impact testing are 180mm length x 130mm width. The mold made from silicone does not affect the mixture of chemicals. Figure 3.5 illustrates the mold made from silicone.

(a) Tensile and Flexural testing

(b) Impact Testing

Figure 3.5 The silicone mold of eco-friendly CLPR composites

The sandwiches manufactured with reinforced material made of polyester resin and hardener contain a certain amount of coconut leaf powder. Firstly, a silicone mould release was used to clean and dry the mold before the polyester resin can be laid up on the mold. Figure 3.6 shows a silicone mould release.

Figure 3.6 Silicone mould release

Weighting the coconut leaf powder according to the desired ratios. Figure 3.7 illustrates the weighting of coconut leaf powder, polyester resin, and hardener. The polyester resin was then mixed uniformly with the hardener by using a stick in the mixed container. Pour the coconut leaf powder that already weighting with the mixture of polyester resin and hardener. Figure 3.8 shows the polyester resin and hardener (Butanox M-50).

(a) Polyester resin (b) Hardener (Butanox M-50) (c) Coconut leaf powder

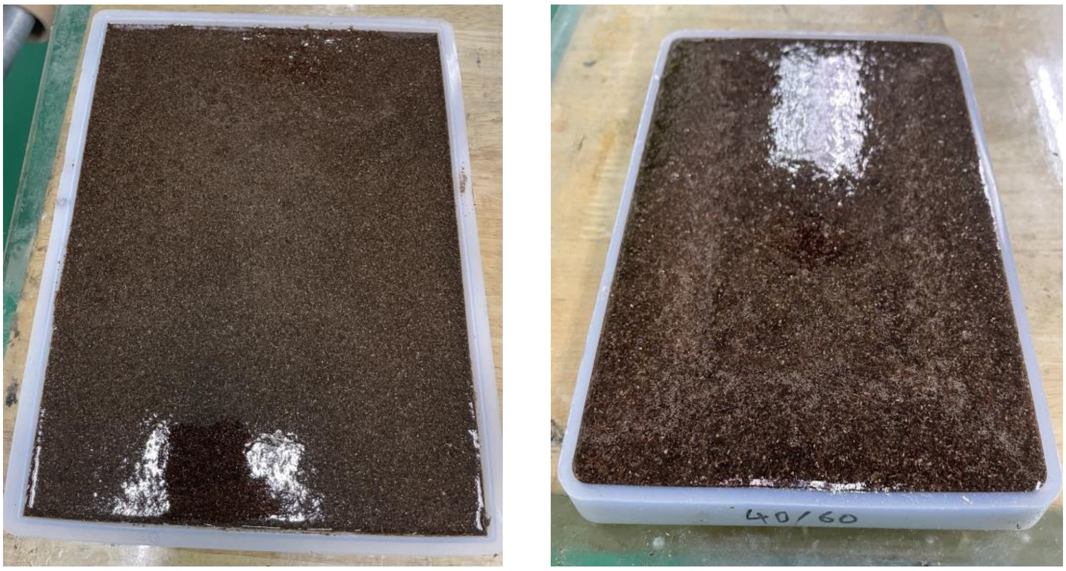
Figure 3.7 Weighting of coconut leaf powder, polyester resin, and hardener

Figure 3.8 Polyester resin and hardener (Butanox M-50)

Mix it until fully uniform. Figure 3.9 illustrates the mixture of the specimen. Then, the mixture was poured carefully into the molds by using hand lay-up techniques to flatten the specimen before being dried for 48 hours. After the composites were fully dried, they were separated from the molds. Figure 3.10 shows the flattening of the specimen before being dried at room temperature for 48 hours.

(a) Mix it until fully uniform (b) The mixture was poured into the mold

Figure 3.9 The mixture of the specimen into the molds



(a) Specimen of the tensile and flexural test (b) Specimen of the impact test

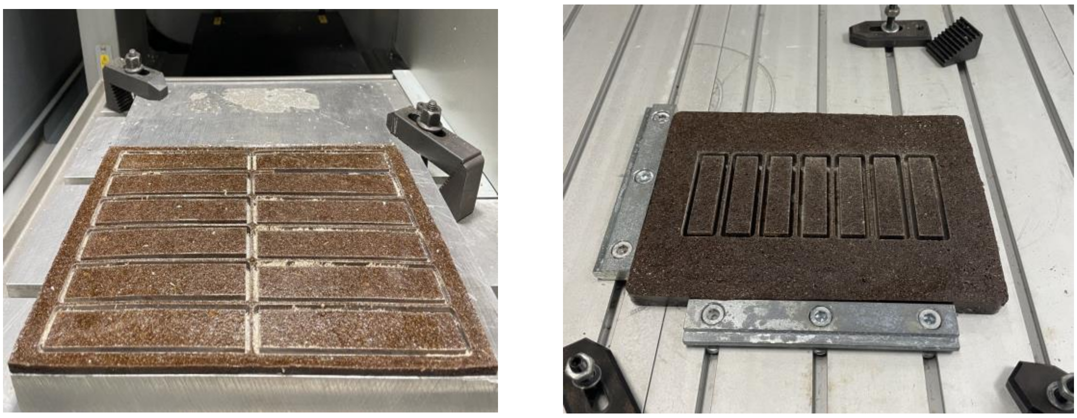
Figure 3.10 The flattening of the specimen before being dried at room temperature for 48 hours

3.4.2 CNC Router Machine Process

After the sample was dry and hardened after 48 hours, the sample was cut using a CNC router machine. The sample has to be cut according to the ASTM standards. Figure 3.11 shows the CNC router machine model MODELA PRO2 (MDX-540). The material test should then be placed on top of the vice to keep it in place. On the computer control panel, the position or coordinate axis must be set to zero. The cutting tool should be at the same location after the coordinates have been confirmed in the form of an NC code. Spindle speeds of 100rpm until 200rpm are used. The cutting procedure is completed by pushing the "output" button on the control panel.

Figure 3.11 The CNC router machine MODELA PRO2 (MDX-540)

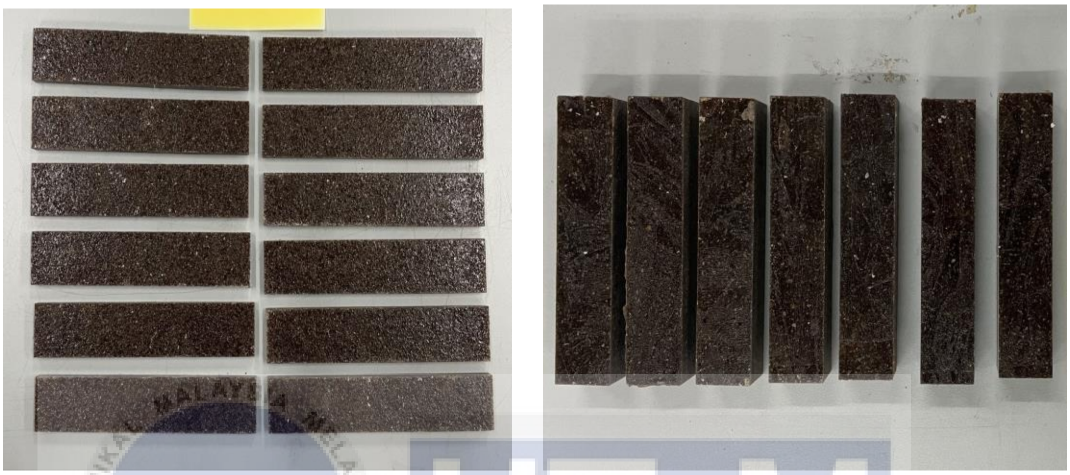
There is consist of three different types of ASTM standards used in this experiment. First and foremost, the tensile testing dimensions are 120mm length x 20mm width x 3mm thickness according to ASTM D3039. Second, the dimensions for flexural testing are 120mm length x 20mm width x 3mm thickness according to ASTM D790. Thirdly, the impact testing dimensions are 55mm length x 12.5mm width x 10mm thickness according to ASTM E23. The samples should be cut according to the specified size. Please be ensure the machine is running in good condition and the cutting tool is placed in the correct position so that the cutting procedure goes smoothly and a good specimen size is obtained. Figure 3.12 illustrates the three types of ASTM standards cut according to a specific size.



(a) ASTM standard of tensile and flexural testing (b) ASTM standard of impact testing

Figure 3.12 The three types of ASTM standards are cut according to a specific size

After completely done the cutting process, it will be tested through tensile testing, flexural testing, and impact testing. Figure 3.13 shows the specific size of the specimen after being cut through the CNC router machine.



(a) Tensile and flexural testing (b) Impact testing

Figure 3.13 The specific size of the specimen after being cut through the CNC router machine

3.4.3 Tensile Testing Process

The specimen material will be tensile tested with a universal testing machine once the coconut leaf composites have been cut. Figure 3.14 shows a Universal Testing Machine model Shimadzu. The test material should be smoothed with sandpaper throughout its whole surface before beginning the tensile procedure. This can help to ensure a seamless material testing process. The test material must be in good condition before beginning the tensile testing. The specimen size of tensile testing is ASTM 3039 (120mm length x 20mm width x 3mm thickness) at 5mm/min for cross-head speed. Figure 3.15 shows the specimen of a tensile at the specimen grips. After a done tensile operation, the tensile test results will be shown on the computer.

Figure 3.14 Universal Testing Machine model Shimadzu

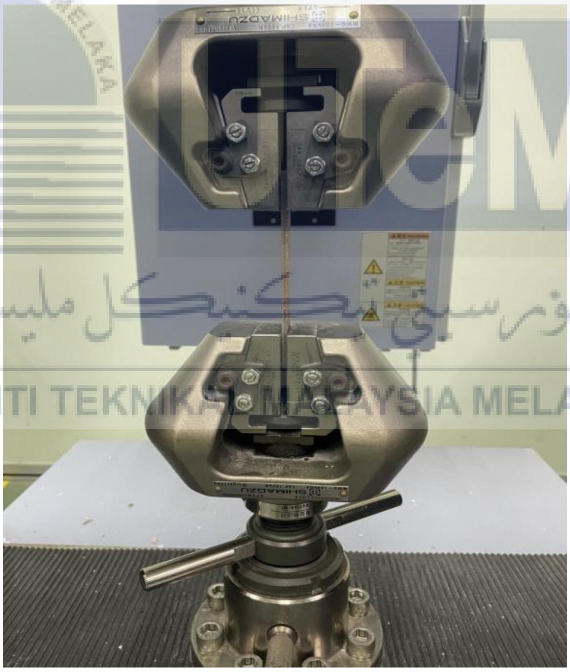


Figure 3.15 The specimen of a tensile test at the specimen grips

3.4.4 Flexural Testing Process (3-point Bending Test)

Flexural testing is used in composites to assess the stiffness and flexural strength of a solid laminate or sandwich construction. In a flexural test, the specimen of coconut leaf reinforced by polyester resin is loaded horizontally in a three-point loading configuration. The convex side of the sheet or plate is tensioned, and the outer fibres are subjected to maximum stress and strain in a 3-point bend test. When the strain or elongation exceeds the material's limits, failure occurs. The force is applied to the centre of the specimen by the loading nose, resulting in three-point bending at a specified rate. This test's parameters are the test's support span, loading speed, and maximum deflection. These parameters are defined variably by ASTM and ISO depending on the thickness of the test specimen. When the specimen reaches a deflection of 5% or breaks before this point, the ASTM D790 test is completed. The ISO 178 test is completed when the specimen breaks. The test is extended as far as practicable if the specimen does not break, with the stress state set at 3.5% (conventional deflection).

The specimen size of flexural testing is ASTM D790 (120mm length x 20mm width x 3mm thickness) at 2mm/min for cross-head speed. Figure 3.16 shows the specimen of a flexural test on the supporting pins. After done this operation, the flexural test results will be shown on the computer. The data that we need for the flexural test will consist of flexural stress at yield, flexural strain at yield, flexural stress at break, flexural strain at break, and so on. While stress/strain curves and raw data also can be provided.

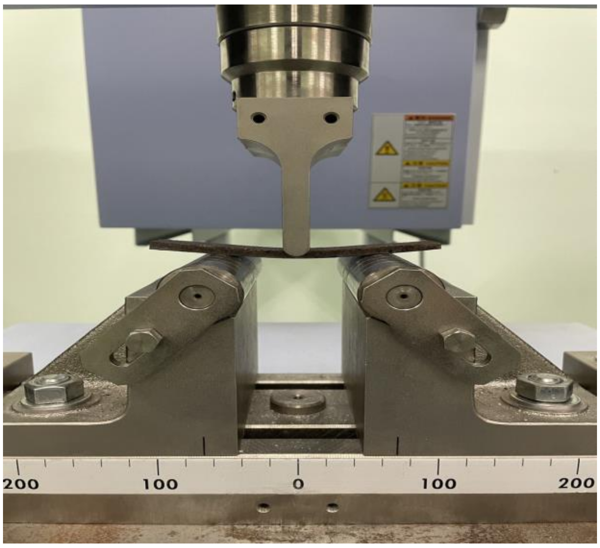


Figure 3.16 The specimen of a flexural test on the supporting pins

3.4.5 Impact Testing Process

In an impact testing process, it will be conducted to study the various characteristics of materials. Toughness, hardness, ductility, and strength are examples. Figure 3.17 illustrates the impact tester machine model INSTRON CEAST 9050.

Figure 3.17 The impact testing machine INSTRON CEAST 9050

In the Charpy method, the specimen needs to have a V-notch before analyzing the result data. The diameter depth of the V-notch is 2mm with an angle of 45 degrees. For impact testing, the specimen size is ASTM E23 (55mm length x 12.5mm width x 10mm thickness). After done the operation, the impact testing result of the data will be recorded successfully. Figure 3.18 shows the specimen of the impact testing on an anvil and struck.

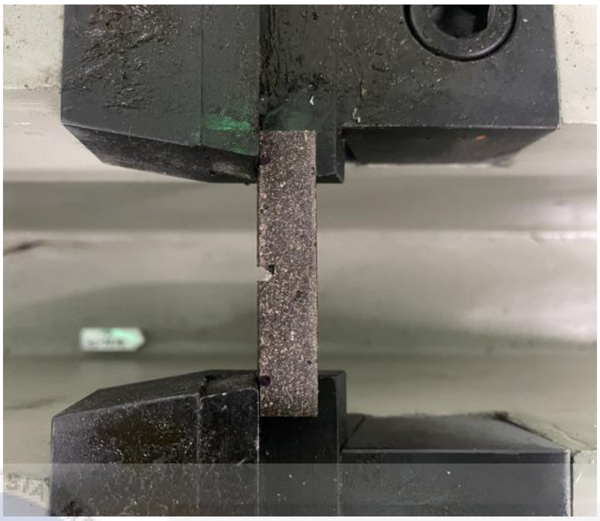


Figure 3.18 The specimen of the impact testing on an anvil and struck

3.4.6 The Analysis of the results using Statistical Analysis (ANOVA)

The final stage is the analysis of the results using statistical analysis. Based on the analyzed results of the mechanical properties, we will be obtained the best ratio on coconut leaf reinforced by polyester resin. ANOVA is a statistical approach for determining if the averages of samples from a population are the same. A one-way analysis of variance (ANOVA) was applied to analyze the energy of the CLPR composites respectively. Expanding ANOVA is utilized in this study by calculating the energy of CLPR composites for all five eco-friendly ratios either significant since the P-value is lower than the significant cut-off level which is $\alpha = 0.05$. It should provide more information for selecting the best composition for the composition material.

3.4.7 Summary

In a nutshell, all of these procedures and preparations must be carried out properly and by the process planned to meet all of the project's objectives. By the end of this chapter, every planning, method, and preparation will have played a significant influence in reaching desired outcomes and results. Finally, all methods must be carefully and correctly followed with no errors to acquire valid results from these tests.

3.5 Gantt Chart

3.5.1 Gantt Chart PSM 1

As shown in Appendix A.

3.5.2 Gantt Chart PSM 2

As shown in Appendix B.

CHAPTER 4

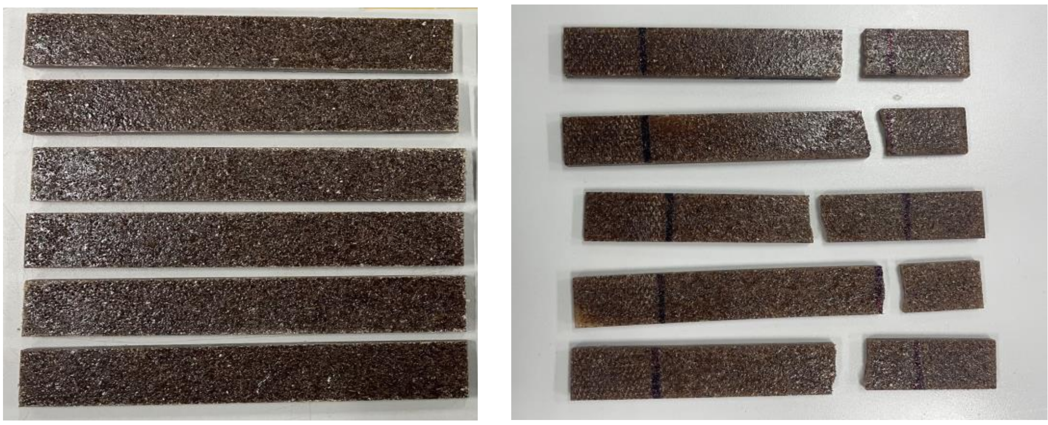
RESULTS AND DISCUSSION

4.1 Introduction

The strength of composites will be discussed mostly in this section. Tests on the CLPR composite will be conducted using the three testing methods of tensile, flexural, and impact. This chapter will examine and clarify the findings of a number of tests that were conducted, along with the computation that was used.

4.2 Tensile Test Results

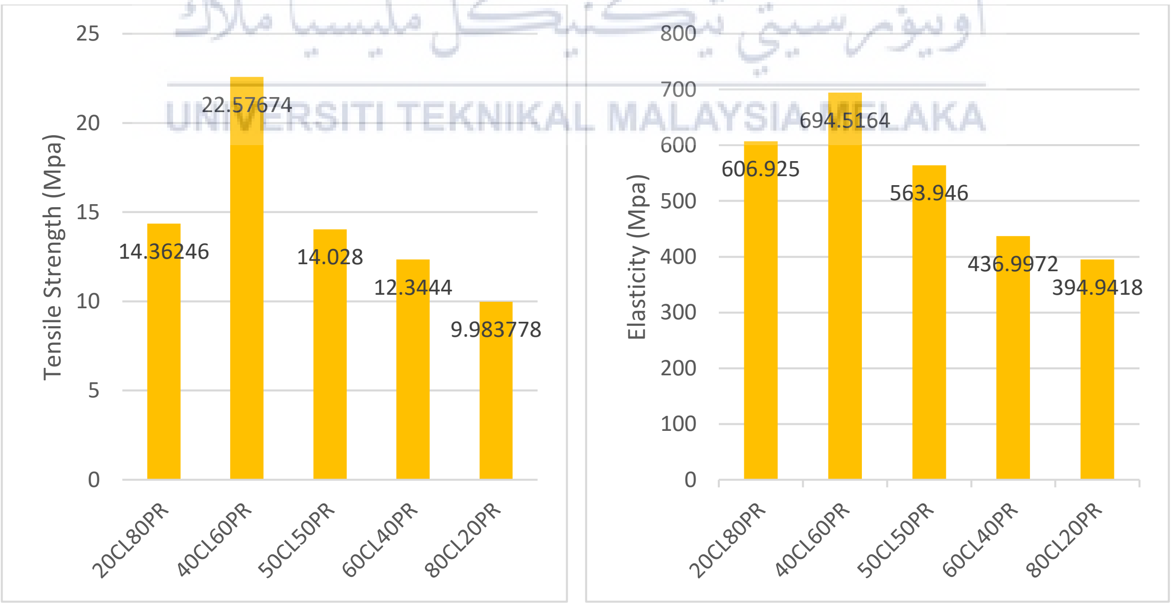
Figure 4.1 illustrates the specimen of the tensile test before and after testing. There are 25 samples for each of the five eco-friendly CLPR composites ratios of 20CL80PR, 40CL60PR, 50CL50PR, 60CL40PR, and 80CL20PR that were tested by using Universal Testing Machine.



(a) Before testing (b) After testing

Figure 4.1 Specimen of the tensile testing

Figure 4.2 illustrates the tensile strength and elasticity values for each of the five eco-friendly CLPR composite ratios of 20CL80PR, 40CL60PR, 50CL50PR, 60CL40PR, and 80CL20PR. The tensile strength and elasticity of 40CL60PR were found to be higher than the CLPR composite ratios. Comparatively, 80CL20PR had the lowest value of tensile strength and elasticity. This observation suggested that the tensile strength of the eco-friendly ratios of CLPR composites becomes stronger as the percentage of coconut leaf is around 40%. Then, a one-way analysis of variance (ANOVA) was applied to analyze the tensile strength and elasticity of the CLPR composites as shown in Tables 4.1 and 4.2, respectively. The results presented that the tensile strength and elasticity of CLPR composites for all five eco-friendly ratios were significant since the P-value is lower than the significant cut-off level which is $\alpha = 0.05$. Therefore, it indicated that all the tensile strength and elasticity for five eco-friendly ratios of CLPR composites have a different averages. As an outcome, the best tensile properties are obtained by combining coconut leaf and polyester resin matrix in proportions of 40% and 60% respectively.



(a) Tensile strength

(b) Elasticity

Figure 4.2 Tensile strength and elasticity for five eco-friendly ratios of CLPR composites.

Table 4.1 ANOVA of tensile strength for five eco-friendly ratios of CLPR composites.

Source of Variation	*SS*	*df*	*MS*	*F-value*	*P-value*
Strength of tensile	451.9589	4	112.9897	52.36159	2.56E-10
Error	43.15748	20	2.157874		
Total	495.1164	24			

Note: *SS = Sum of Squares , df = Degrees of Freedom, MS =Mean Square, F=test statistic*

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

$$T_\alpha = q_\alpha(a,f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{2.157874}{5}} = 2.785$$

From the calculation, any pairs of treatment averages with absolute value differences more than 2.785 would suggest that the associated pair of population means is significantly different. The five treatment averaging results are as follows:

$$\overline{y}_{1.} = 14.36246 \quad \overline{y}_{2.} = 22.57674$$

$$\overline{y}_{3.} = 14.028 \quad \overline{y}_{4.} = 12.3444$$

$$\overline{y}_{5.} = 9.983778$$

and the differences in averages :

$$\overline{y}_{1.} - \overline{y}_{2.} = 14.36246 - 22.57674 = -8.214^{*}$$

$$\bar{y}_{1.} - \bar{y}_{3.} = 14.36246 - 14.028 = -0.334$$

$$\bar{y}_{1.} - \bar{y}_{4.} = 14.36246 - 12.3444 = -2.018$$

$$\bar{y}_{1.} - \bar{y}_{5.} = 14.36246 - 9.983778 = 4.379^{*}$$

$$\bar{y}_{2.} - \bar{y}_{3.} = 22.57674 - 14.028 = 8.549^{*}$$

$$\bar{y}_{2.} - \bar{y}_{4.} = 22.57674 - 12.3444 = 10.232^{*}$$

$$\bar{y}_{2.} - \bar{y}_{5.} = 22.57674 - 9.983778 = 12.593^{*}$$

$$\bar{y}_{3.} - \bar{y}_{4.} = 14.028 - 12.3444 = 1.684$$

$$\bar{y}_{3.} - \bar{y}_{5.} = 14.028 - 9.983778 = 4.044^{*}$$

The pairs of means with significantly different started values are shown by the started values. The Tukey procedure, it should be noted, shows that all pairs of means are different. As a result, we can conclude that the mean etch rate at power setting is different from the mean etch rate at other power setting.

Table 4.2 ANOVA of elasticity for five eco-friendly ratios of CLPR composites.

Source of Variation	*SS*	*df*	*MS*	*F-value*	*P-value*
Elasticity of tensile	302888.6	4	75722.14	7.82248	0.000577
Error	193601.4	20	9680.068		
Total	496489.9	24			

Note: *SS = Sum of Squares , df = Degrees of Freedom, MS = Mean Square F=test statistic*

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

$$T_\alpha = q_\alpha(a,f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{9680.068}{5}} = 186.561$$

From the calculation, any pairs of treatment averages with absolute value differences more than 186.561 would suggest that the associated pair of population means is significantly different. The five treatment averaging results are as follows:

$$\bar{y}_{1.} = 606.925 \quad \bar{y}_{2.} = 694.5164$$

$$\bar{y}_{3.} = 563.946 \quad \bar{y}_{4.} = 436.9972$$

$$\bar{y}_{5.} = 394.9418$$

and the differences in averages :

$$\bar{y}_{1.} - \bar{y}_{2.} = 606.925 - 694.5164 = -87.591$$

$$\bar{y}_{1.} - \bar{y}_{3.} = 606.925 - 563.946 = 42.979$$

$$\bar{y}_{1.} - \bar{y}_{4.} = 606.925 - 436.9972 = 169.928$$

$$\bar{y}_{1.} - \bar{y}_{5.} = 606.925 - 394.9418 = 211.983^{*}$$

$$\bar{y}_{2.} - \bar{y}_{3.} = 694.5164 - 563.946 = 130.570$$

$$\bar{y}_{2.} - \bar{y}_{4.} = 694.5164 - 436.9972 = 257.519^{*}$$

$$\bar{y}_{2.} - \bar{y}_{5.} = 694.5164 - 394.9418 = 299.575^{*}$$

$$\bar{y}_{3.} - \bar{y}_{4.} = 563.946 - 436.9972 = 126.949$$

$$\bar{y}_{3.} - \bar{y}_{5.} = 563.946 - 394.9418 = 169.004$$

The pairs of means with significantly different started values are shown by the started values. The Tukey procedure, it should be noted, shows that all pairs of means are different. As a result, we can conclude that the mean etch rate at power setting is different from the mean etch rate at other power setting.

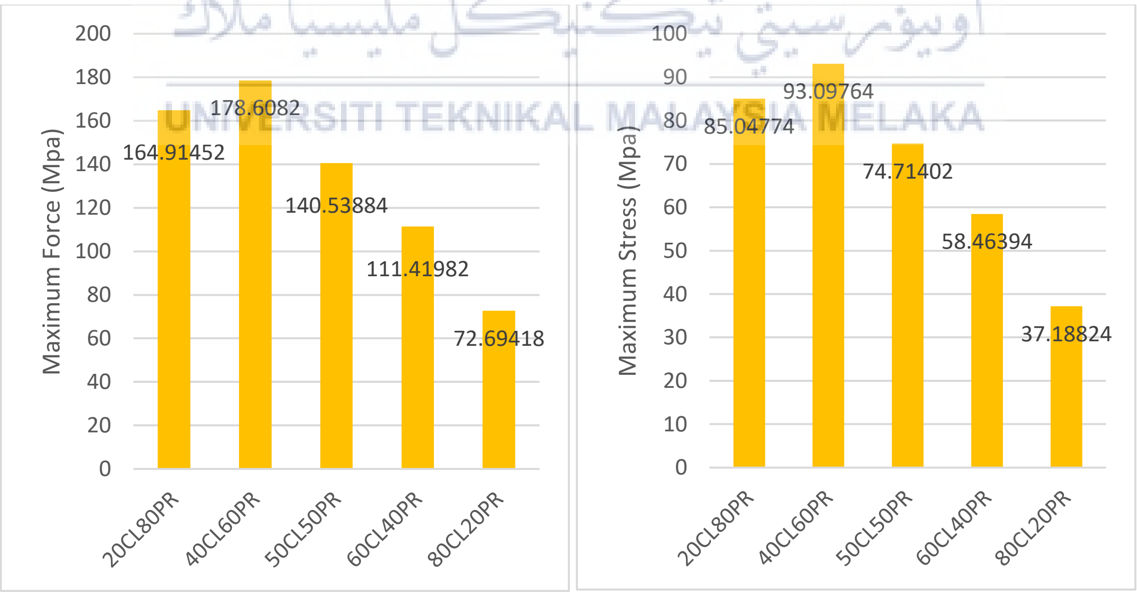
4.3 Flexural Test Results

Figure 4.3 illustrates the specimen of the flexural test before and after testing. There are 25 samples for each of the five eco-friendly CLPR composites ratios of 20CL80PR, 40CL60PR, 50CL50PR, 60CL40PR, and 80CL20PR that were tested by using Universal Testing Machine.

(a) Before testing (b) After testing

Figure 4.3 Specimen of the flexural testing

Figure 4.4 illustrates the maximum force and maximum stress values for each of the five eco-friendly CLPR composite ratios of 20CL80PR, 40CL60PR, 50CL50PR, 60CL40PR, and 80CL20PR. By using universal testing equipment, the mechanical characteristics of CLPR composite materials were evaluated at a cross-head speed of 2 mm/min. The test specimens underwent bending tests in accordance with the ASTM D790-07 flexural testing standard. The maximum force and maximum stress of 40CL60PR were found to be higher than the CLPR composite ratios. Comparatively, 80CL20PR had the lowest value of maximum force and stress. This observation suggested that the maximum force of the eco-friendly ratios of CLPR composites becomes stronger as the percentage of coconut leaf is around 40%. Then, a one-way analysis of variance (ANOVA) was applied to analyze the maximum force and maximum stress of the CLPR composites as shown in Tables 4.3 and 4.4, respectively. The results presented that the maximum force and maximum stress of CLPR composites for all five eco-friendly ratios were significant since the P-value is lower than the significant cut-off level which is $\alpha = 0.05$. Therefore, it indicated that all the maximum force and maximum stress for five eco-friendly ratios of CLPR composites have different averages. As an outcome, the best flexural properties are obtained by combining coconut leaf and polyester resin matrix in proportions of 40% and 60% respectively. In addition, the CLPR composite for coconut leaf composition of 60% and 80% is not suitable for the composite material because it illustrated the lower value for mechanical properties. Thus, too many fibres can destroy the structure of the polymer itself and decline in its flexural strength.



(a) Maximum force (b) Maximum stress

Figure 4.4 Maximum force and maximum stress for five eco-friendly ratios of CLPR composites

Table 4.3 ANOVA of maximum force for five eco-friendly ratios of CLPR composites.

Source of Variation	*SS*	*df*	*MS*	*F-value*	*P-value*
Strength flexural	36279.79	4	9069.947	93.18663	1.23E-12
Error	1946.62	20	97.331		
Total	38226.41	24			

Note: *SS = Sum of Squares , df = Degrees of Freedom, MS =Mean Square, F=test statistic*

Using Tukey's test, two means are deemed to be substantially different if their sample difference's absolute value is greater. To illustrate Tukey’s test, we use the data from the plasma etching experiment in Table 4.3. with $\alpha = 0.05$ and $f = 20$ degrees of freedom for error. From Table VII (see Douglass C *et al.*, 2023), gives $q_{0.05}(5,20) = 4.24$. Therefore, we have,

$$T_{\alpha} = q_{\alpha}(a,f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{97.331}{5}} = 18.707$$

From the calculation, any pairs of treatment averages with absolute value differences more than 18.707 would suggest that the associated pair of population means is significantly different. The five treatment averaging results are as follows:

$$\bar{y}_{1.} = 164.91452 \quad \bar{y}_{2.} = 178.6082$$

$$\bar{y}_{3.} = 140.53884 \quad \bar{y}_{4.} = 111.41982$$

$$\bar{y}_{5.} = 72.69418$$

and the differences in averages :

$$\bar{y}_{1.} - \bar{y}_{2.} = 164.91452 - 178.6082 = -13.694$$

$$\bar{y}_{1.} - \bar{y}_{3.} = 164.91452 - 140.53884 = 24.376^{*}$$

$$\bar{y}_{1.} - \bar{y}_{4.} = 164.91452 - 111.41982 = 53.495^{*}$$

$$\bar{y}_{1.} - \bar{y}_{5.} = 164.91452 - 72.69418 = 92.220^{*}$$

$$\bar{y}_{2.} - \bar{y}_{3.} = 178.6082 - 140.53884 = 38.069^{*}$$

$$\bar{y}_{2.} - \bar{y}_{4.} = 178.6082 - 111.41982 = 67.188^{*}$$

$$\bar{y}_{2.} - \bar{y}_{5.} = 178.6082 - 72.69418 = 105.914^{*}$$

$$\bar{y}_{3.} - \bar{y}_{4.} = 140.53884 - 111.41982 = 29.119^{*}$$

$$\bar{y}_{3.} - \bar{y}_{5.} = 140.53884 - 72.69418 = 67.844^{*}$$

The pairs of means with significantly different started values are shown by the started values. The Tukey procedure, it should be noted, shows that all pairs of means are different. As a result, we can conclude that the mean etch rate at power setting is different from the mean etch rate at other power setting.

Table 4.4 ANOVA of maximum stress for five eco-friendly ratios of CLPR composites.

Source of Variation	*SS*	*df*	*MS*	*F-value*	*P-value*
Strength flexural	9957.033	4	2489.258	51.42847	3.02E-10
Error	968.0469	20	48.40234		
Total	10925.08	24			

Note: *SS = Sum of Squares , df = Degrees of Freedom, MS = Mean Square*, *F=test statistic*

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

$$T_\alpha = q_\alpha(a,f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{48.40234}{5}} = 13.192$$

From the calculation, any pairs of treatment averages with absolute value differences more than 13.192 would suggest that the associated pair of population means is significantly different. The five treatment averaging results are as follows:

$$\bar{y}_{1.} = 85.04774 \quad \bar{y}_{2.} = 93.09764$$

$$\bar{y}_{3.} = 74.71402 \quad \bar{y}_{4.} = 58.46394$$

$$\bar{y}_{5.} = 37.18824$$

and the differences in averages :

$$\bar{y}_{1.} - \bar{y}_{2.} = 85.04774 - 93.09764 = -8.050$$

$$\bar{y}_{1.} - \bar{y}_{3.} = 85.04774 - 74.71402 = 10.333$$

$$\bar{y}_{1.} - \bar{y}_{4.} = 85.04774 - 58.46394 = 26.584^*$$

$$\bar{y}_{1.} - \bar{y}_{5.} = 85.04774 - 37.18824 = 47.860^*$$

$$\bar{y}_{2.} - \bar{y}_{3.} = 93.09764 - 74.71402 = 18.384^*$$

$$\bar{y}_{2.} - \bar{y}_{4.} = 93.09764 - 58.46394 = 34.634^*$$

$$\bar{y}_{2.} - \bar{y}_{5.} = 93.09764 - 37.18824 = 55.910^*$$

$$\bar{y}_{3.} - \bar{y}_{4.} = 74.71402 - 58.46394 = 16.250^*$$

$$\bar{y}_{3.} - \bar{y}_{5.} = 74.71402 - 37.18824 = 37.526^*$$

The pairs of means with significantly different started values are shown by the started values. The Tukey procedure, it should be noted, shows that all pairs of means are different.

As a result, we can conclude that the mean etch rate at power setting is different from the mean etch rate at other power setting.

4.4 Impact Test Results

Figure 4.5 illustrates the specimen of the impact test before and after testing. There are 25 samples for each of the five eco-friendly CLPR composites ratios of 20CL80PR, 40CL60PR, 50CL50PR, 60CL40PR, and 80CL20PR that were tested by using Impact Testing Machine.

(a) Before (b) After

Figure 4.5 Specimen of the impact test

Figure 4.6 illustrates the energy values for each of the five eco-friendly CLPR composite ratios of 20CL80PR, 40CL60PR, 50CL50PR, 60CL40PR, and 80CL20PR. The test specimens underwent impact tests in accordance with the ASTM E23 Impact testing standard. The energy of 40CL60PR was found to be higher than the CLPR composite ratios which are 0.288 (J). Comparatively, 80CL20PR had the lowest value of energy (0.04 J). This observation suggested that the energy of the eco-friendly ratios of CLPR composites becomes stronger as the percentage of coconut leaf is around 40%. Then, a one-way analysis of variance (ANOVA) was applied to analyze the energy of the CLPR composites as shown in Tables 4.5, respectively. The results presented that the energy of CLPR composites for all five eco-friendly ratios was significant since the P-value is lower than the significant cut-off level which is α = 0.05. Therefore, it indicated that all the energy for five eco-friendly ratios of CLPR composites has different averages. As an outcome, the best impact properties are obtained by combining coconut leaf and polyester resin matrix in proportions of 40% and 60% respectively.

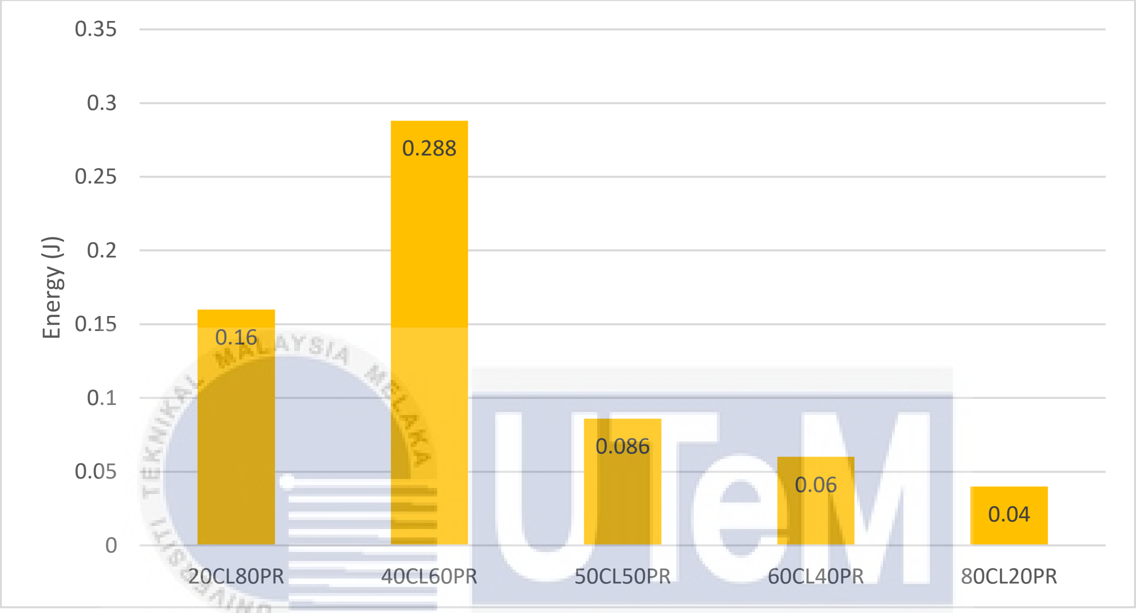


Figure 4.6 The impact strength for five eco-friendly ratios of CLPR composites.

Table 4.5 ANOVA of impact strength for five eco-friendly ratios of CLPR composites.

Source of Variation	*SS*	*df*	*MS*	*F-value*	*P-value*
Strength of impact	0.203744	4	0.050936	113.1911	1.94E-13
Error	0.009	20	0.00045		
Total	0.212744	24			

Note: *SS = Sum of Squares , df = Degrees of Freedom, MS = Mean Square, F=test statistic*

Using Tukey's test, two means are deemed to be substantially different if their sample difference's absolute value is greater.To illustrate Tukey’s test, we use the data from the plasma etching experiment in Table 4.5. with $\alpha = 0.05$ and $f = 20$ degrees of freedom for error. From Table VII (see Douglass C *et al.*, 2023), gives $q_{0.05}(5,20) = 4.24$. Therefore, we have,

$$T_{\alpha} = q_{\alpha}(a,f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{0.00045}{5}} = 0.040$$

From the calculation, any pairs of treatment averages with absolute value differences more than 0.040 would suggest that the associated pair of population means is significantly different. The five treatment averaging results are as follows:

$$\overline{y}_{1.} = 0.16 \quad \overline{y}_{2.} = 0.288$$

$$\overline{y}_{3.} = 0.086 \quad \overline{y}_{4.} = 0.06$$

$$\overline{y}_{5.} = 0.04$$

and the differences in averages :

$$\overline{y}_{1.} - \overline{y}_{2.} = 0.16 - 0.288 = -0.128^{*}$$

$$\overline{y}_{1.} - \overline{y}_{3.} = 0.16 - 0.086 = 0.074^{*}$$

$$\overline{y}_{1.} - \overline{y}_{4.} = 0.16 - 0.06 = 0.1^{*}$$

$$\overline{y}_{1.} - \overline{y}_{5.} = 0.16 - 0.04 = 0.12^{*}$$

$$\overline{y}_{2.} - \overline{y}_{3.} = 0.288 - 0.086 = 0.202^{*}$$

$$\overline{y}_{2.} - \overline{y}_{4.} = 0.288 - 0.06 = 0.228^{*}$$

$$\overline{y}_{2.} - \overline{y}_{5.} = 0.288 - 0.04 = 0.248^{*}$$

$$\overline{y}_{3.} - \overline{y}_{4.} = 0.086 - 0.06 = 0.026$$

$$\overline{y}_{3.} - \overline{y}_{5.} = 0.086 - 0.04 = 0.046^{*}$$

The pairs of means with significantly different started values are shown by the started values. The Tukey procedure, it should be noted, shows that all pairs of means are different. As a result, we can conclude that the mean etch rate at power setting is different from the mean etch rate at other power setting.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter summarises the findings and recommendations for further research from this experiment. The goal of this study was to use three different testing procedures such as tensile testing, flexural testing, and impact testing in order to improve the data on how to archive a good quality of strength material on coconut leaf composite.

5.2 Conclusion

To successfully complete this research, three goals must be achieved. Mechanical characteristics of a composite made using filler components like waste coconut leaf reinforced polyester resin. The specimen was made by mixing 20% of CL and 80% of polyester resin, 40% CL and 60% of polyester resin, 50% CL and 50% of polyester resin, 60% CL and 40% of polyester resin, and 80% CL and 20% of polyester resin volume of CLPR composite. Since the investigation on mechanical characteristics utilising the tensile test, flexural test, and impact test of the CLPR composite was successful, everything has been archived through this experiment. Tensile, flexural, and impact tests have been effectively used to investigate the mechanical properties of coconut leaf reinforced by polyester resin. Tensile testing, flexural testing, and impact testing are all performed on all specimens in accordance with the ASTM standard. Moreover, the hand lay-up method was used to fabricate the specimen. It is crucial to confirm that the specimen was produced with high-quality materials. Based on the previous result, it shows that the tensile strength and elasticity of 40CL60PR were found to be higher than the CLPR composite ratios which is tensile strength (22.57674 MPa) and elasticity (694.5164 MPa). Comparatively, 80CL20PR had the lowest value of tensile strength (9.983778 MPa) and elasticity (394.9418 MPa). This observation suggested that the tensile strength of the eco-friendly ratios of CLPR composites becomes stronger as the percentage of coconut leaf is around 40%. Then, a one-way analysis of variance (ANOVA) was applied to analyze the tensile strength and elasticity of the CLPR composites.

While the flexural testing, the maximum force and maximum stress of 40CL60PR were found to be higher than the CLPR composite ratios with maximum force (178.6082 MPa) and maximum stress (93.09764 MPa). Comparatively, 80CL20PR had the lowest value of maximum force (72.69418 MPa) and stress (37.18824 MPa). The results presented that the maximum force and maximum stress of CLPR composites for all five eco-friendly ratios were significant since the P-value is lower than the significant cut-off level which is $\alpha = 0.05$. Therefore, it indicated that all the maximum force and maximum stress for five eco-friendly ratios of CLPR composites have different averages. Other than that, this means that the percentage of coconut leaf with 40% and polyester resin 60% becomes stronger than the other ratios of CLPR composites respectively.

As a result of the impact testing, the coconut leaf reinforced polyester resin with a percentage of coconut leaf 40% and polyester resin 60% have better energy (0.288 Joule) compared to the other eco-friendly ratios of CLPR composites. For the ANOVA results, it can be concluded that the impact strength of five eco-friendly ratios of CLPR composites were significant since the P-value is (1.94E-13) lower than the significant cut-off level which is $\alpha = 0.05$. Last but not least, the best impact properties are obtained by combining coconut leaf and polyester resin matrix in proportions of 40% and 60% respectively.

5.3 Recommendation

For upcoming research, it is recommended to add other mechanical tests on CLPR composites such as compression tests to study, investigate and analyse more mechanical properties of CLPR composites. Moreover, it also recommended doing physical tests on composite materials including water absorption. Using this physical test, the water resistance of the coconut leaf in the bio-composites will be demonstrated. In order to improve the outcome of future research, it is also advised to incorporate more variable weight percentages of the reinforcement values.

5.4 Project Potential

These composites can be defined as multipurpose material to be used in different sector. For examples, composite materials are now used as components for buildings, and structures, such as swimming pool panels, storage tanks, interior components, and other parts. Moreover, the use of composites in automotive industry have also lead to the substituition of numerous traditional materials in the manufacture of dashboard, door panel, and engine compartment. Composite materials, when directly compared to steel, may satisfy the material requirements for the automobile sector, including corrosion resistance in damp conditions and high-impact strength to sustain repeated usage. It may be concluded that the obtained results of CLPR composites are not negotiable and may be of potential value since it encourages higher utilisation of already-existing natural fibres and its composites will be beneficial to the economy of the country.

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APPENDICES

APPENDIX A Gantt Chart PSM 1

ACTIVITIES	**STATUS**	**WEEK**															
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Supervisor Selection And Registered Title	Plan	🟥	🟥	🟥													
	Actual	🟩	🟩	🟩													
Brief And Project Explanation By Supervisor	Plan	🟥	🟥	🟥													
	Actual	🟩	🟩	🟩													
Module 1: Research Design And Planning	Plan		🟥														
	Actual		🟩														
Discuss Problem Statement And Objective For Chapter 1	Plan			🟥													
	Actual			🟩													
Drafting And Writing Chapter 1	Plan	🟥	🟥	🟥	🟥												
	Actual		🟩	🟩	🟩	🟩											
Module 2: Final Year Project Literature Review	Plan			🟥	🟥	🟥	🟥										
	Actual					🟩	🟩										
Drafting And Writing Up Chapter 2	Plan				🟥	🟥	🟥	🟥									
	Actual					🟩	🟩	🟩	🟩	🟩	🟩						
Module 3: Research Methodology	Plan				🟥	🟥											
	Actual				🟩	🟩											
Drafting And Writing Up Chapter 3	Plan							🟥	🟥	🟥	🟥						
	Actual							🟩	🟩	🟩	🟩	🟩					
Recheck Chapter 1,2 And 3	Plan									🟥	🟥	🟥	🟥	🟥			
	Actual									🟩	🟩	🟩	🟩	🟩	🟩		

APPENDICES

APPENDIX B Gantt Chart PSM 2

ACTIVITIES	**STATUS**	**WEEK**															
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Meeting And Discussion	Plan	🟥															
	Actual	🟦															
Conducting The Experiment	Plan	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥							
	Actual	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦							
Collecting Data And Analysis on Sample	Plan	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥							
	Actual	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦							
Make a Discussion On Result	Plan	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥							
	Actual	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦						
Drafting And Writing Chapter 4	Plan		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥							
	Actual			🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦						
Drafting And Writing Chapter 5	Plan									🟥	🟥						
	Actual									🟦	🟦						
First’s Submission Draft PSM 2	Plan										🟥						
	Actual										🟦						
Second’s Submission Draft PSM	Plan											🟥					
	Actual											🟦					
Submission Full Report PSM 2	Plan												🟥				
	Actual												🟦				
Make A Correction Of Full Report	Plan													🟥	🟥		
	Actual													🟦	🟦		
Oral Presentation PSM 2	Plan														🟥	🟥	
	Actual														🟦	🟦	