EXPERIMENTAL ANALYSIS ON MECHANICAL PROPERTIES OF GLASS FIBER COCONUT LEAF REINFORCED WITH POLYESTER RESIN

MUHAMMAD AIDIL HAQIEM BIN AZHAR

B092010149

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

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MUHAMMAD AIDIL HAQIEM BIN AZHAR

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Tarikh: 11 / 01 / 2024

Cop Rasmi:

DR. ISKANDAR BIN WAINI
Pensyarah Kanan
Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan
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Supervisor Name : DR. ISKANDAR BIN WAINI

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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. Azhar bin Abd.Manan and Mrs.Norliza Bint Saaid. Finally, I'd like to thank my supervisor, Dr. Iskandar Bin Waini for all of his help, guidance, and advice in completing this thesis

ABSTRACT

The usage of natural fibres in composites has increased in recent years due to the growing awareness of the need of protecting the environment via the utilisation of biodegradable materials. Fibre reinforced polymer-based composites have been utilised in a wide variety of industrial applications for a very long time due to the high specific strength and modulus that these composites possess. Because there are so many natural fibres that may be obtained, it was decided to look into the possibility of employing coir, which is also a natural fibre, as reinforcement in polymers that are reinforced. The cost of natural fibres is commensurate with their superior properties of strength and lightness. As a result, the purpose of this study is to look into the mechanical characteristics of coconut leaf reinforced polyester resin. For the purpose of completing this project, the hand lay-up technique will be utilised in the manufacturing of the necessary materials. The next step is the cutting of the manufactured materials with a CNC router machine in accordance with the requirements set by the ASTM. Following the completion of the cutting procedure, the samples will be subjected to tensile, flexural, and impact testing in order to ascertain their respective levels of mechanical characteristics. Statistical analysis was used to do the analysis on the data that were obtained

ABSTRAK

Penggunaan gentian semula jadi dalam komposit telah meningkat sejak beberapa tahun kebelakangan ini kerana kesedaran yang semakin meningkat tentang keperluan untuk melindungi alam sekitar melalui penggunaan bahan terbiodegradasi. Komposit berasaskan polimer bertetulang gentian telah digunakan dalam pelbagai jenis aplikasi perindustrian untuk masa yang sangat lama kerana kekuatan dan modulus spesifik yang tinggi yang dimiliki oleh komposit ini. Oleh kerana terdapat begitu banyak gentian semula jadi yang boleh diperolehi, diputuskan untuk melihat kemungkinan menggunakan sabut, yang juga merupakan gentian asli, sebagai tetulang dalam polimer yang diperkukuh. Kos gentian semulajadi adalah sepadan dengan sifat unggul kekuatan dan ringannya. Hasilnya, tujuan kajian ini adalah untuk melihat ciri-ciri mekanikal damar poliester bertetulang daun kelapa. Bagi tujuan menyiapkan projek ini, teknik letak tangan akan digunakan dalam pembuatan bahan yang diperlukan. Langkah seterusnya ialah pemotongan bahan perkilangan dengan mesin penghala CNC mengikut keperluan yang ditetapkan oleh ASTM. Selepas selesai prosedur pemotongan, sampel akan tertakluk kepada ujian tegangan, lenturan dan hentaman untuk memastikan tahap ciri mekanikal masing-masing. Analisis statistik digunakan untuk melakukan analisis terhadap data yang diperolehi.

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LIST OF SYMBOLS AND ABBREVIATIONS

Nf	-	Natural Fiber
CLPR	-	Coconut Leaf and Polyester Resin
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CHAPTER 1

INTRODUCTION

1.1 Background

Environmentally friendly materials are being created today with the goal of achieving sustainable global development. Many researchers have discovered the potential of natural fibre as reinforcement in polymer composites as a result of their concern for the environment. The term "natural fibres" describes fibres that come from both plants and animals. Natural fibres like bamboo, hemp, jute, and oil palm may be used in place of synthetic fibres to create composites that are biodegradable, light, and have enhanced mechanical qualities. Certain chemical alterations can improve these mechanical qualities. Additionally, these fibres' morphology may be altered using a variety of chemical processes to enhance mechanical interlocking. This overview discusses the characteristics of natural fibres including jute, bamboo, oil palm, and hemp as well as the most recent prospective uses to create sustainable and profitable values.(Kurien et al., 2023)

Natural fibres are favoured over synthetic ones since they are more environmentally friendly. Natural fibre reinforcement in polymers results in composite materials with great strength and stiffness. Banana, bamboo, sugarcane, jute, kenaf, flax, palm, sisal, hemp, coir, ramie, and abaca are among the most popular natural fibres produced worldwide. These fibres from natural sources are less expensive, lighter, recyclable, and non-toxic by nature. In addition to these benefits, natural fibre also has good mechanical, insulation, and machine-wearing features. Due to all of these characteristics, this natural fibre is a great reinforcement for composites made of polymers.(Sahu et al., 2023)

Accoding to statistic, the demand for coconut is growing annually, and Malaysia is home to the 12-largest coconut sector. According to Malaysia's Ministry of Agriculture, the average annual intake is 17.0 kilogramme. This demonstrates that the coconut tree is among the most significant for the economy, whether as a plant, fruit, or source of agricultural waste. Due to the accessibility of the coconut tree, coconut shells have emerged as one of the primary sources of pollution, accounting for more than 60% of the country's total trash volume and producing around 3.18% million tonnes of pollution yearly. Coconut husk, mesocarp, coir (fibre), and all other portions of waste from coconuts may be utilised in a variety of ways.(Omar et al., 2023)

For this composite, the material required is coconut leaf. Large, green leaves called "coconut leaves" develop in groups near the summit of the coconut tree. They are 2-3 feet broad and 6-10 feet long. Each leaf consists of many leaflets that are arranged in a fan-like design. The flexible and thin leaflets may endure heavy winds. Coconut leaves are durable, lightweight, and water-resistant. They provide a large amount of fibre as well. In this research, composites made from coconut leaves were altered to create panels with various matrix variations and reinforcing elements. The analysis will involve the use of impact, flexural, and tensile testing.

In this study, the mechanical properties of a natural composite made of coconut leaf, fibre glass, and polyester resin were tested to determine its specific strength. To accomplish this, a 3-point Bending Test, a Universal testing machine and Charpy impact test were used to construct the composite and test it in a variety of settings.(Yamini et al., 2023)

1.2 Problem Statement

The industrial sector in Malaysia has seen significant expansion in recent years. As a direct consequence of this, the utilisation of various materials in the production of new items in the manufacturing industry as well as in regular life would increase. The rising need for recycled materials in the industrial industry will be a major driver of the growth in the demand for raw aggregate.

The creation of natural fibres is influenced by a variety of factors, including plants, animals, and geological processes. In this experiment, coconut leaves are being exploited as a natural fibre source. One of the most long-lasting and naturally occurring fibres is coconut fibre. However, the cohesion and ductility of a composite are both negatively impacted by an increase in the amount of coconut fibre contained within it. As a consequence of this, the research will centre on finding ways to lessen the amount of resin that was required to remove composite materials in order to find a solution to this issue. In addition, the tensile strength grows together with the fibre weight during the manufacturing process. In addition, an option manufactured from waste products that are less harmful to the environment is coconut leaf. The majority of people in Malaysia incorporate coconut into their everyday meals. The leaves of the coconut tree are frequently thrown away and burnt. Because it is effective in reducing musculoskeletal pain, coconut leaf has the potential to be used in place of aggregate produced from trash. Another method for treating the discomfort is to soak in the combination.

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 with fibre glass and polyester resin.

b) To study the mechanical properties of coconut leaf reinforced with fibre glass 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 project aims to investigate the mechanical properties of coconut leaf reinforced with fiber glass and polyester resin. This study will consist of four stages. Utilising the manual lay-up technique, the materials are fabricated as the initial step. During the second stage, the CNC router is used to transform the material into the test specimen. The specimen's mechanical properties are evaluated in the third stage using tensile, flexural, and impact tests. It is essential to obtain the finest results possible and to compare them to previous research. The final step involves the statistical analysis of the results. On the basis of the mechanical property analysis, we will determine the optimal ratio for coconut leaf reinforced with polyester resin.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A composite material is a material composed of two or more separate materials that have been combined to generate a material with properties distinct from those of the constituent materials. The respective materials are referred to as the matrix and the reinforcement. The matrix is the surrounding continuous phase. Reinforcement is the discontinuous phase that contributes to the composite's strength and rigidity. In this chapter, a number of various research on fibre, natural fibres, coconut leaf fibre, and polymer composites are summarised, along with their conclusions. In order to investigate the mechanical characteristics of coconut leaf reinforced with fiber glass and polyester resin, the information that was obtained through the research of the relevant literature served as the foundation for the investigation.

Researchers and engineers are becoming increasingly interested in the possibility of using polymeric materials that are reinforced with natural fibres rather than conventional fibres. It's because of the various benefits that come along with using NFs, such how easy they are to decompose, how friendly they are to the environment, how cheap they are, and how light they are.(Khalid et al., 2021)

Different configurations of glass fibre layers have a significant impact on the mechanical characteristics, even when the ratio of glass fibre material to total volume remains the same. The tensile strength and impact strength of the samples with carbon fibre layers centred arrangement mode and those with two fibre layers evenly dispersed arrangement mode are comparable, which is much superior than that of the samples with glass fibre layers centred arrangement mode (Ding et al., 2023)

The qualities of a composite material are determined by the properties of the matrix, those of the reinforcement, and the manner in which the matrix and reinforcement are joined. In a typical composite, the matrix is responsible for providing the material with its toughness and impact resistance. In most cases, the reinforcement is responsible for providing the composite with its strength and stiffness.

2.2 Need fr Composite

Recent environmental consciousness has made the development of natural fibre composite materials or environmentally friendly composites a popular topic of discussion. Natural fibres are an efficient alternative to synthetic materials and their derivatives for applications requiring less weight and energy conservation. Natural fibre composites have excellent specific characteristics, but their properties are highly variable. With the advancement of natural fibre and composite processing, their weaknesses can and will be eliminated (Getu et al., 2020). The advantages of the composite are shown in Table 2.1.

Table 2.1 The Advantages of Composites

Advantages of Composite	
❖ High strength	❖ Light weight density
❖ Design flexibility	❖ A long-life expectancy
❖ Toughness	❖ High resistance to corrosion
❖ Stiffness	❖ Reduced cost
❖ Extremely durable	❖ Thermal & electrical insulation or conductivity

Table 2.1 is not a complete list of desirable characteristics. The most important characteristic of composite materials is that their properties are met, i.e., the necessary attributes can be designed.

2.3 Type of Composite

On the basis of the matrix, there are three different types of composite materials: metal matrix composites (MMCs), ceramic matrix composites (CMCs), and polymer matrix composite (PMCs) materials. Among the different types of composite materials, fibre and particle reinforced polymer matrix composites have begun to contribute to a substantial amount of the market.(Getu et al., 2020). When designing a PMC, it is necessary to take a number of considerations into mind. In order to produce a structural material that is optimally suited to the conditions in which it will be utilised, it is necessary to strictly regulate a large number of different parameters. Continuous-fiber reinforcement is required in PMCs in order to realise the goal of isotropy in the mechanical properties of these materials. To put it another way, PMCs are at their most stable when they are stressed in a direction that is perpendicular to their fibre orientation, and they are at their most fragile when they are stretched in a direction that is parallel to the fibres.

A composite material having a metal matrix that is reinforced with ceramic or metal particles is referred to as a metal matrix composite, or MMC for short. The matrix is the continuous phase of the MMC, and it is commonly composed of a metal like aluminium, magnesium, or titanium. The matrix may also be referred to as the matrix phase. The structure and resilience of the MMC are both derived from the matrix. The reinforcement is the dispersion phase of the MMC, and it is commonly composed of a ceramic material, such as silicon carbide (SiC) or alumina (Al2O3). The reinforcement contributes both to the strength and the stiffness of the MMC. Most frequent metal matrix composites are aluminium matrix composites. In addition to higher wear resistance, decreased density, and superior corrosion resistance, greater specific strength, specific stiffness, and raised temperature strength are some of the major advantages of aluminium matrix composites. Other advantages include corrosion resistance..

Ceramic matrix composites, also known as CMCs, are made up of one or more reinforcements in addition to a ceramic matrix. These reinforcements can take the form of fibres, whiskers, carbon nanotubes (CNTs), graphene, particulates, or other materials. The utility of these composites is in addition to their exceptional strength and resistance to wear, outstanding fracture toughness, high-temperature stability, and great thermal shock resistance.(Sun et al., 2023)

Continuous phase of the composite material consists of polymer matrix, metal matrix, and ceramic matrix. The matrix material serves multiple purposes, including securing the reinforcement and distributing the load. One of the two components of the composite material is the dispersed phase, also known as the reinforced material. In automotive engines, the heat resistance, abrasion resistance, thermal conductivity, and high-temperature strength of the material are all crucial factors. Moreover, they can be mass-produced and are cost-effective. Typically, aluminium alloys are used to construct the matrix. Copper, aluminium, and other metals are frequently employed as substrates for industrial integrated circuits and heat dissipation components due to their high thermal conductivity and low expansion rates. Metal matrix composites may be efficiently strengthened by the incorporation of continuous fiber-reinforced materials. Since fibre is used as a reinforcing material, the strength and modulus are greater than those of a metal matrix.(Dixit et al., 2017)

2.4 Type of Matrix Composite

By reinforcing fibres in a polymer matrix, composite material enhances construction efficiency, resulting in a new structure known as hybrid composite, which has a wide variety of material properties (Hatti et al., 2022). A composite material's matrix is its continuous aspect. It is the material that retains the reinforcement and transmits burdens between the reinforcement fibres. Typically, a polymer, ceramic, or metal serves as the matrix. Resins are a form of polymer that serve as the matrix in numerous composite materials. The majority of resins are thermosetting or thermoplastic polymers. After mixing with a hardener, thermosetting resins cure (harden), whereas thermoplastic resins can be liquefied and reshaped. Each chemical family of the resin system is designed and commissioned to provide industries with unique benefits including cost, structural performance, resistance to various causes, and regulatory compliance.

Thermosets and thermoplastics are the two major groups of resins that fall within the broader category of polymer materials. Resins like this are often manufactured using polymer. In addition, thermoset resins were utilised throughout the production of the superior composites. When employed to manufacture final items, the thermoset resin is "cured" by being subjected to either heat or catalysts, or a mixture of the two. After it has been healed, a thermoset resin that has solidified cannot be reverted to its previous liquid condition. Typical examples of thermosets are polyester, vinyl ester, epoxy, and polyurethane.. 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
• Highly impact-resistant • Highly recyclable • Reshaping capabilities • Chemical resistant	• Expensive • Can melt if heated • UV light may cause degradation

Table 2.3 Advantages and Disadvantages of Thermoset

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

2.5 Thermoplastic

The term "thermoplastic" refers to a class of polymers that, when melted, may be recast into practically any shape. When heated, they become liquid, but after being cooled, they solidify. Thermoplastics, on the other hand, transform into a glass-like state when frozen, making them more likely to crack. These properties, which are responsible for giving the material its name, are reversible, which means that the material may be again warmed, reshaped, and frozen. Because of this, thermoplastics may be recycled through the mechanical process. Polypropylene, polyethylene, polyvinylchloride, polystyrene, polyethylenetheraphthalate, and polycarbonate are examples of some of the thermoplastics that are most often used. Thermoplastics have been in existence for a very long time and are an integral part of modern life. For example: 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.

The molecular structure of thermoplastics is rather straightforward, as it is made up of macromolecules that are chemically distinct from one another. They are pliable or melted after being heated, then moulded, sculpted, and welded before being allowed to cool and harden into their final form. It is possible to go through many cycles of heating and cooling, which paves the way for recycling and reprocessing.

Using short-term fibres, thermoplastic products are reinforced. Thermoplastic products are reinforced with short-term filaments. Carbon fibre and fibreglass are the finest reinforcing materials. As bonding agents, thermosetting polyester polymers are frequently used in fibreglass laminations. Polyester resins are less expensive compared to competitive epoxy resins. Using hardeners, these polymers initiate a chemical reaction that leads to curing.

2.6 Thermoset

A thermoset is a form of polymer that is produced by irreversibly hardening (or "curing") a flexible solid or viscous liquid prepolymer (resin). Curing is induced by heat or suitable radiation and can be accelerated by high pressure or catalyst-enhanced mixture. The resin's reaction with a curing agent (catalyst, hardener) generates heat, so it is not always necessary to apply heat externally. In the matrix of this composite mechanical material is a strong structural fibre. Listed below are some of the most typical thermoset resins: Polyester and Vinyl Ester Resins are examples of resins.

2.7 Fibre

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

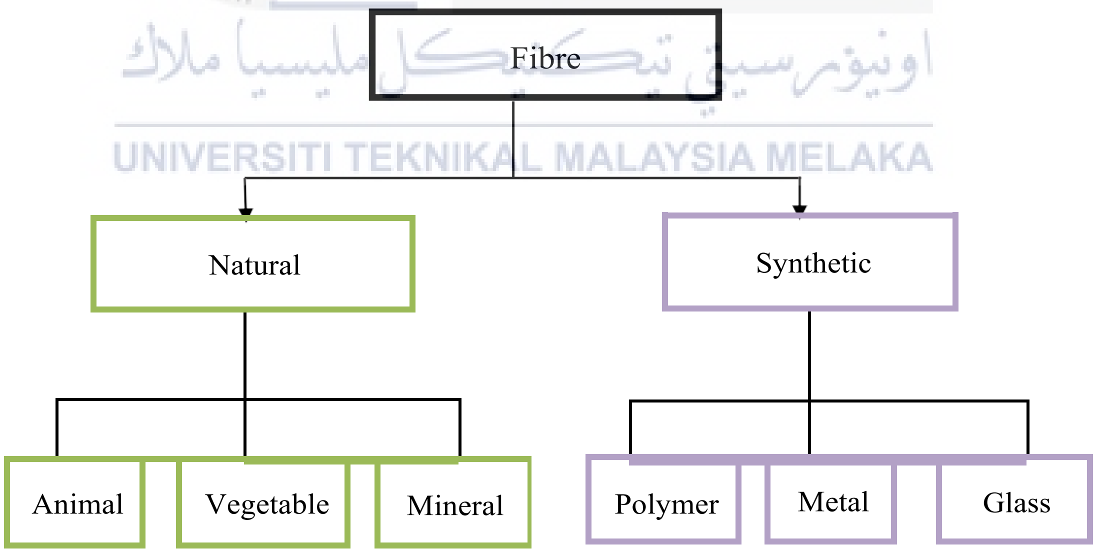

Figure 2.7: The classification of fibres is based on natural and synthetic fibres

Natural fibre composites consist of natural fibres, such as bamboo, flax, or hemp, encased in a polymer matrix. Natural fibre composites are gaining in prominence due to their low cost and sustainability. However, they are not quite as strong as composites made of glass fibre or carbon fibre. Synthetic fibres include polymer, metal, and glass.

NF such as sisal, jute, coir, and silk are inexpensive, readily available, biodegradable, durable, and lightweight. Similar to jute, NF has the potential to replace conventional reinforcement in composite materials for application sectors requiring a high strength-to-weight ratio and a low weight. Both fibres are biodegradable and recyclable (Dattatreya et al. 2023).

Natural fibres derived from plants are obtained from renewable resources and are relatively inexpensive compared to synthetic fibres. In addition, natural fibres are simple to manipulate and generate no known substantial environmental issues. A study of the mechanical properties and microstructures of mortar containing coconut, jute, and kelp fibre reinforcements revealed that these natural fibres enhanced the mortar's strength and durability. In addition, the effect of jute fibre length and content on the mechanical properties of concrete was investigated (Choi 2022).

The material known as fibreglass composite is constructed by impregnating glass fibres with a resin. While the resin acts as a binder to keep the glass fibres together, the glass fibres give the material its strength and rigidity. Composites made of fibreglass are distinguished by their low weight, high strength, and resistance to corrosion. The mechanical characteristics of the composite made with carbon fibre reinforced polymer are shown to be superior than those made with glass fibre reinforced polymer. On the other hand, catastrophic failure can be observed in carbon fibre composites due to the poor elongation of carbon fibre (Jesthi et al. 2018).

2.8 Natural Fibers

Protein and cellulose are the primary components of animal and plant fibres, respectively. In addition to stems, leaves, seeds, xylem, bark, and fruit, the fibre plant also has stems. Fibres are produced from either primary or secondary meristematic tissue, depending on the species. The stem fibre also consists of wheat, bagasse, rice, bamboo and maize stem. Fruit fibres include oil palm and coconut, whereas leaf fibres include abaca, sisal, and agave. In addition, cotton, kapok, and many other plants are examples of seed fibres. Wool, silk, avian feather, hair, and collagen fibres are examples of like fibres, while bark fibres include rosella, jute, hibiscus, abaca, soybean fibre, and ramie. Mineral fibres include glass, carbon, and asbestos, among others(Jino et al. 2023).

The sustainability of construction materials is a growing concern, and the use of natural fibres (NFs) is one method to develop alternative, inexpensive, renewable raw materials. The outstanding performance of NF can be found in cement-based materials containing these filaments, which can be used to reduce environmental warnings. NFs play a significant role in reinforcing the mechanical behaviour of cement concrete, particularly the tensile and flexural strengths. Significant disadvantages of NF include comparatively high moisture absorption and hydrophilic behaviour, resulting in decreased adhesion between the concrete matrix and fibres, which negatively impacts the overall performance of concrete material. Due to a decrease in water absorption or an increase in surface irregularity, the application of physical and chemical remedies can increase the NF cement components' resistance to ageing (Jino et al. 2023).

2.9 Work Material

The term "work material" refers to materials, instruments, equipment, components, installations, facilities, supplies, and resources that are necessary for the task execution but are not to be included in or consumed during engineering manufacture. Work material may also refer to work-related goods. For this project, we will be using a wide range of materials.

2.10 Coconut Leaf

Both in terms of their practical application in industry and their place in basic research, there has been a recent uptick in interest in natural fibre reinforced polymer composites materials. They are entirely or partially recyclable and biodegradable, as well as renewable and inexpensive. Plants, such as wood, which have been utilised since the beginning of time as sources of lignocellulose fibres, are increasingly being employed as reinforcement of composites in a variety of applications(Bharath et al. 2022). In many regions of the world, coconut leaf is one of the most affordable materials. The Philippines and India are the next two countries on the list when it comes to the production of coconuts after the world leader, which is Indonesia.

Because coconut leaves can reach lengths of up to 6 metres and are quite resilient, they are excellent materials for thatching and weaving. Coconut trees may live for up to 100 years. The leaves are segmented into leaflets, which are then placed in a spiral formation over the surface of the leaf. The leaflets have a robust and leathery texture, and their colour is a dark forest green. The leaves of the coconut tree may be used to a number of different uses, including thatching roofs, manufacturing brooms, and weaving baskets. Because of their pliability, coconut leaves may be bent and shaped in a variety of ways, making them an ideal material for use in weaving and other creative activities. Because coconut leaves are not affected by moisture, they are an excellent choice for use as a roofing material or in the construction of outdoor furniture. Because of their low weight, coconut leaves are convenient to transport and simple to deal with. Coconut leaves are an eco-friendly alternative to man-made materials since they are made of a natural and renewable resource called coconut palm fibre.

The coconut palm, scientifically known as Cocos nucifera L., is often regarded as both a beautiful and practical tree native to tropical regions. More than ninety nations participate in its manufacturing, with the majority of global output coming from Asia and the Pacific. Coconuts are grown on around 80 percent of the world's total agricultural land area, with the Philippines, Indonesia, India, Sri Lanka, Thailand, Malaysia, and Papua New Guinea accounting for the remaining 20 percent (Pham 2016). Each part of the coconut palm has a significant commercial value. Because coconut contains anti-viral elements, the market for coconut-based products has become the industry with the highest rate of growth. Even the shells may be utilised as crafting materials because the coconut itself is used to manufacture oils. The wood from coconut trees has been used to produce brooms, and other uses for wood include making furniture, construction materials for homes, and hardwood flooring. It demonstrates how people all around the world have had to adapt their means of subsistence as a result of the growing of coconut palms. The Philippines, Indonesia, and India are the top three nations in terms of the economic benefits that have been derived from the cultivation of coconut palms. Farmers need to be educated about the economic worth of coconuts in order for there to be an increase in output. This is because there is a strong demand for items created from coconuts all over the world.

In this study, polyester matrices are reinforced with coconut leaf filaments derived from natural refuse. The purpose of this material was to examine the mechanical properties of coconut leaf waste materials reinforced with polyester resin.

2.11 Properties of Coconut Leaf

Coconut palm, (Cocos nucifera), palm of the family Arecaceae, cultivated extensively in tropical areas for its edible fruit, the coconut. Coconut palms are found in tropical coastal areas nearly worldwide and probably originated somewhere in Indo-Malaya. They are the most economically important palm species, coconuts being one of the predominant crops of the tropics. The density of natural fibres is low, and they are readily available including low cost, and availability in a variety of forms throughout the world (Bharath et al. 2022b).

The typical behaviour of coconut leaves adjusts in accordance with the geographical location, the climatic conditions of the season, and the species. The tensile strength of coconut leaves can be attributed, in part, to the high cellulose and lignin content of the leaves (Jishnu, Sankar, and Chandrakaran 2020). Coconut is a plant with several uses. When compared to other natural fibres, the tenacity of coconut fibres is unparalleled. They have the potential to be employed as reinforcement in low-cost concrete constructions, particularly in parts of the tropics that are prone to earthquakes (Ali et al. 2012). However, the leaves of this plant are not particularly useful. Typically, the leaves are only cultivated for use in handicrafts and decorative purposes.

The tensile strength of the natural fibres in coconut leaflets is determined by cellulose fibrils as well as amorphous components such as lignin and hemicellulose. When natural fibre comes into contact with the soil matrix, which absorbs water, it speeds up the process of biodegradation and causes the fibre to inflate. This presents a significant challenge for the natural fibre (Jishnu, Sankar, and Chandrakaran 2020b).

2.12 Application of Coconut Fibre

Coconut and coir fibres, their composites, and various "applications," "abstract": "In light of the fact that plastic has emerged as the material of choice in the modern world, a lot of focus has been placed on the research and development of bio-based plastics and polymers, as well as the composites containing these materials. Coir fibre is a type of biomaterial that is often extracted from vegetables and utilised in a variety of applications. For the purpose of the production of bio-composites, coir fibres are being utilised as a reinforcing component in polymers, either in their treated or untreated form. In addition, coir fibres are increasingly being employed as reinforcement in ceramic-based composites, particularly in concrete-based materials. Researchers have a growing interest in the usage of biofibers as a result of the growing need for biocomposites in a variety of applications as a result of the demand for environmentally friendly composites in different industries, including the car, packaging, electronic, health, and structural industries. Therefore, this study on coir fibre, its composites, and applications is crucial for the promotion of the future development of environmentally friendly composites (Oladele et al. 2022).

According to (Hwang et al. 2016), the incorporation of short coconut fibre in cementitious composites has the potential to alter both the impact resistance and the plastic cracking behaviour of the composites. They demonstrated that coconut fibre reinforced cementitious composites displayed improvement in their flexural behaviour despite some loss being detected in their compressive strength. This was done despite the fact that they demonstrated improvement in their flexural behaviour. All of the cementitious composites that included coconut fibre showed excellent resistance to impact testing.

2.13 Cutting Process Machine

The CNC router machine will be used throughout the course of the project to carry out the task of cutting created materials into test specimens. In addition, the specimens are sliced according to a specified size range, certain criteria, and with the right tool eye speed. This is done before they are examined. As a result, the researchers that have employed this machine as a tool to cut specimens will be included in our review of the relevant literature.

2.14 CNC Router Machine

CNC stands for Computerized Numerical Control. It brings the automation scenario to the field of machining processes. This type of machine can operate 24hrs non-stop for 365 days with minimal need to switch off other than for maintenance purposes. Generally programmed with machining codes (G-code &M−code) according to the design of the required product. Once the code is fed into the machine we can repeat the process numerous times with minimal human labor, we can also alter dimensions and other small features in the machine itself with less effort (Barik et al. 2023).

The main focus of this study is to develop and build a 3-axis CNC milling machine that is not only inexpensive but also portable and entirely modifiable. The process of additive manufacturing will be employed for the production of the vast bulk of the machine's structural components. By utilising this strategy, it will be possible to take substantial benefit of quick prototyping, easy customization, and a decrease in costs (Kumar et al. 2022).

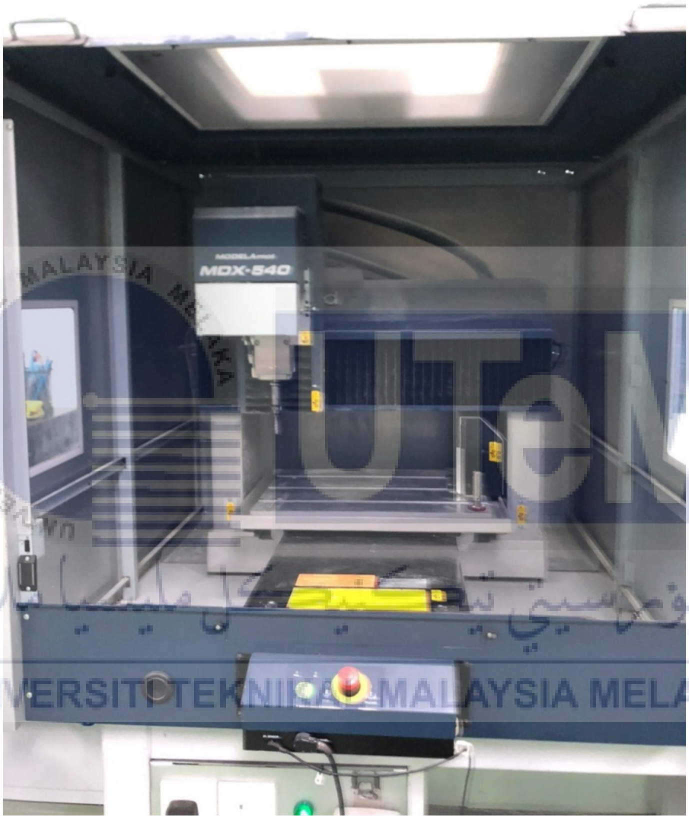

Figure 2.14 CNC Router Machine

The fundamental difference between CNC milling and CNC router is the material that may be machined. Both CNC milling and CNC routing are examples of subtractive manufacturing methods that involve the use of computer-controlled equipment to carve away material. On the other hand, there are a few significant distinctions between the two procedures. When it comes to cutting materials, a CNC router makes use of a revolving router bit, whereas a CNC mill makes use of a spinning end mill. End mills are often used for cutting tougher materials such as metal and acrylic, whilst router bits are typically used for cutting softer materials such as wood and plastic. Router bits are typically used for cutting softer materials. In most cases, soft materials like wood and plastic are the kinds of things that are cut with CNC routers. In addition to that, you may use them to cut non-ferrous metals like aluminium and brass using them. Cutting through tough materials using a CNC mill, such as titanium and steel, is a typical use for this type of machine. In addition to that, you may use them to cut ferrous metals like iron and steel using them.

2.15 Cutting Parameters

a. **Cutting speed:** The rate at which the tool being used to cut is being moved. The standard unit of measurement for it is metres per minute (m/min).

b. **Depth of cut:** The quantity of material that is taken from a piece of material by using the cutting tool many times. Millimetres (mm) are the standard units of measurement for it.

The maximum depth is determined by the diameter of the tool, so the depth of incision cannot exceed the diameter of the tool. A greater depth of cut may reduce time, but it may also cause the instrument to shatter or shorten its lifespan.

c. **Feed rate:** The speed at which the cutting tool is moved forward through the material. The standard unit of measurement for it is millimetres per minute, abbreviated mm/min.

These parameters should be selected with precision. If the parameters are not set appropriately, the sound of the instruments as they pass through can be heard. In the worst case scenario, the chips may catch fire, which cannot be controlled as it travels through the conduit collector.

2.16 Mechanical Testing

Mechanical testing is a procedure that is used to assess the mechanical characteristics of a material. These qualities might be important in a variety of applications. It is possible to utilise it to assess a material irrespective of the geometry of the material being evaluated as well as under predetermined geometrical criteria.

Tensile testing, fracture testing, fatigue testing, creep testing, impact testing, hardness testing, and non-destructive testing are just some of the many different types of mechanical tests that may be performed to assess various qualities.

Mechanical testing must be part of every design and production process. When defining material characteristics or providing certification for finished products, safety is of paramount importance. Testing is essential for ensuring a cost-effective design, technological advancement, and technological superiority. This assignment will be completed by testing the specimen's mechanical properties with tensile, flexural, and impact tests. It is essential to achieve the finest feasible outcome and compare to previous research.

2.17 Tensile Test

Due to the fact that the tensile test was utilised in this investigation, it is impossible to ascertain the surface condition of the sample utilising only one's naked eyes while the test is being conducted. Observing the surface condition of the material with an electron microscope was similarly difficult due to the complexity of the instrument. This is as a result of the size restrictions as well as the constraints of the environment (Muflikhun and Yokozeki 2023).

A tiny and thin specimen consisting of metals, polymers, or metallic alloys may be tested with the newly invented UTM because it was created with that specific load range in mind. Only the thin, miniaturised specimens are eligible for testing because of the loading capacity of the designed apparatus, the procedures involved in specimen preparation, and the handling of the specimens. This apparatus is equipped to perform tensile testing on samples that are up to 8 centimetres in length (Singh 2022).

Figure 3 depicts the tensile strain in relation to the tensile tension for various composite specimen combinations. The results indicated that composite A has a breaking load of 13.4 N and a modulus of 297.6 MPa, while composite B has a breaking load of 7.6 N and a modulus of 1000 MPa, and composite C has a breaking load of 10.7 N and a modulus of 562.28 MPa. Figure 3 demonstrates that jute samples have exceptional tensile strength and can withstand up to 16.6 MPa. The tensile strength of the fibre can be affected by a variety of factors, including fibre characterization, fibre size, biodegradable property, chemical property, matrix type, number of layers of epoxy-resin and fibre layer, and fibre orientation in matrixes. Figure 4 demonstrates that the composite C has the highest elongation percentage at

8.33%, while composite A (50/50 by weight, jute/coconut) has the lowest at 4.7%.The developed UTM is intended for testing tiny, thin samples of metals, polymers, and metallic alloys within the specified load range. For testing purposes, only thin, miniaturised specimens are suitable in terms of the loading capacity of the developed apparatus, specimen preparation, and specimen handling. This apparatus can analyse tensile samples up to 8 cm in length.

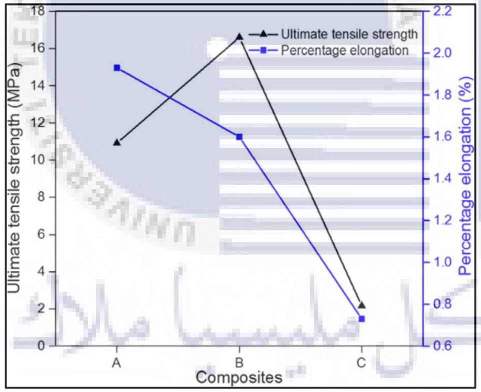

Figure 3 tensile stress for different combinations

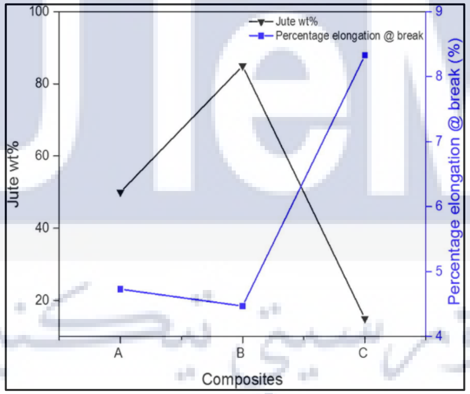

Figure 4 50/50% by weight, jute/coconut

2.18 Flexural Test (3-Point Bending)

Flexural testing is a mechanical procedure used to determine a material's flexural strength and flexural modulus. Flexural modulus is a measure of a material's rigidity under bending loads. Flexural strength is a measure of a material's capacity to withstand bending loads. In a flexural test, a specimen is subjected to an escalating burden until it fails. The burden is applied to the specimen's centre, and the specimen is supported at two locations on either side of the applied load. As the load increases, the specimen's deflection is measured. A material's flexural strength is determined by the load at which the specimen fails. A material's flexural modulus is determined by the slope of the load-deflection curve

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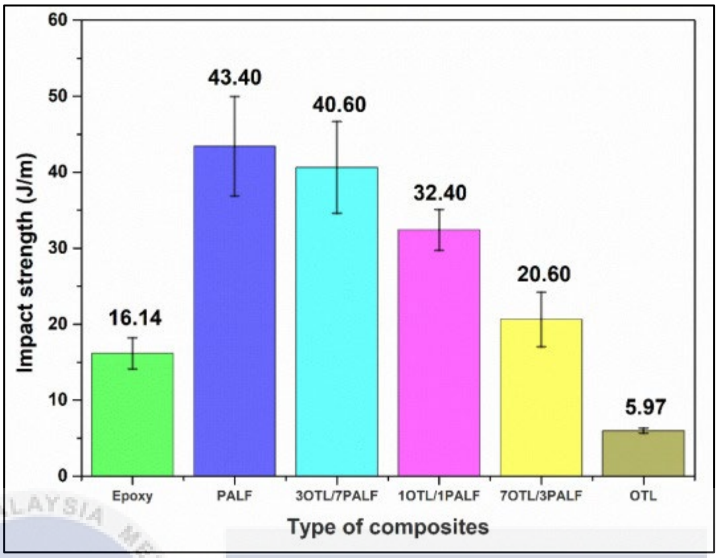
2.19 Impact Test

The ability of a material to withstand the force of an impact is evaluated with the use of a mechanical test called an impact test. A material's resistance to unexpected fracture may be measured using something called its impact toughness. An impact test involves putting a specimen through a rapid stress in order to determine how much energy the specimen can take before it breaks. This energy is quantified. The Charpy impact test and the Izod impact test are the two primary kinds of impact tests that may be performed. After the specimen has been notched for the Charpy impact test, it is subjected to being struck by a pendulum. The amount of energy that is lost by the pendulum is used as a measurement of the amount of energy that is absorbed by the specimen before it fractures. The specimen is notched before being subjected to an Izod impact test, in which a striker is dropped from a predetermined height and hits the specimen. The amount of energy that the striker loses is used as a measurement of the amount of energy that is absorbed by the specimen before it fractures. Impact tests are utilised to measure the impact toughness of a broad variety of materials, including metals, polymers, and composites, amongst others. The findings of impact testing can be included into the design of components that are subjected to unexpected loads, such as the bumpers on automobiles and the lenses of safety glasses.

The hybridised composites' impact strength was found to be superior to that of the OTL/epoxy composites. It took place as a result of the inclusion of PALF. The increase in impact strength was 57% and 97%, respectively, when the PALF loading in hybrid composites went from 10% by weight to 20% by weight and 30% by weight, respectively. As a result, by hybridising PALF with OTL, we were able to acquire a synergistically increased impact strength.

Figure 3 depicts the impact resistance of hybrid composites comprised of PALF/epoxy, OTL/epoxy, and PALF/OTL/epoxy. The impact strength of PALF/epoxy and hybridised composites was discovered to be greater than that of the epoxy matrix alone. Moreover, it was evident from Fig. 3 that increasing the amount of OTL in the epoxy and PALF decreased the impact strength.



2.20 The Analysis of result using Statistical Analysis (ANOVA)

Analysis of Variance, more often known as ANOVA, is a statistical technique that is applied when comparing the averages of two or more groups. It is a strong tool that may be used to assess if there is a statistically significant difference between the means of the groups. One usage of this tool is to determine whether or not there is a difference between the means of the groups.

ANOVA is able to do its analysis because the whole variation in the data is split into two parts:

- The variation that occurs as a result of differences in the means of the groups is referred to as the variance that occurs between groups.
- The variance that occurs inside a group is referred to as the within-group variance. This volatility is caused by random causes, such as measurement error.

According to the findings in Table 6, the shape of the fibre has the most significant impact on tensile strength of all the characteristics that were investigated. Fibre shape is the most significant parameter in terms of statistical significance, with a p-value of 0.002 and a contribution of 40.74%. On the other hand, colour has the least influence on tensile strength, with a contribution of 10.34% and a p-value that is more than 0.05, which means that it is not possible to consider it a statistically significant characteristic. In addition, the fibre weight fraction and orientation angles are also statistically significant characteristics, each contributing 13.51 and 19.97 percent respectively to the total. The findings of the current study are in agreement with those found in other studies, such as [62,63]. As a result, all critical characteristics and their values, as indicated in the table that displays the average performance (Table 5), were already included in the Taguchi's orthogonal array design that was utilised, and they were consistent with Trial 1 (Hiwa, Ahmed, and Rostam 2023).

Parameters	DOF	SS	V	F-test	P %	P-value
Fiber Orientation Angles (A)	1.00	43.22	43.22	12.93	19.97	0.005
Fiber Weight Fraction (B)	2.00	29.24	14.62	4.37	13.51	0.043
Fiber Form (C)	2.00	88.16	44.08	13.19	40.74	0.002
Fiber Color (D)	2.00	22.37	11.19	3.35	10.34	0.077
Residual error	10.00	33.43	3.34		15.45	
Total	17.00	216.41				

Table 2.4 ANOVA Table for tensile strength.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter contains in-depth information on the processes or techniques that were utilised in the search for, selection of, and analysis of data pertaining to this matter. This chapter's section on the methodology gives the reader the opportunity to conduct an in-depth critical analysis of the dependability of the entire procedure. In order to accomplish the currently assigned work target, the process flow is being utilised in this research. The researcher in question makes use of the process flow in order to accomplish the current job aim. The results of this study will be presented in four stages. The creation of the materials by hand using the lay-up technique constitutes the initial stage of the process. While the second stage involves utilising a CNC router machine to cut the created material into the testing specimen, the first stage involves fabricating the material. Tests of tensile strength, flexural strength, and impact strength are used in the third stage, which evaluates the mechanical characteristics of the specimen. It is essential to acquire the best possible result, and it is also important to examine previous study. The third step is an examination of the findings via the lens of statistical methodology. On the basis of the findings of the analysis of the mechanical characteristics, we will be able to acquire the optimal ratio on coconut leaf that has been reinforced with polyester resin. Last but not least, the specifics of the experiments were described in this chapter.

3.2 Project Experiment Process

In the context of this project, the block diagram for the parameter analysis that affects the cutting process with two distinct machines is presented in Table 3.1. For the purposes of this project, there is just one kind of machinery that is used to cut the material. Before the experiment can begin, a material of such significance needs to be prepared. The materials used in the construction were coconut leaf and polyester resin.

A CNC router machine is going to be required in order to cut the coconut leaf. The feed rate and thickness of the experimental specimen are both determined by using the input parameters in their respective ways. After the cutting procedure has been finished and the result has been obtained, the outcome parameters of the cutting method will be analysed. The samples come in three sizes: 250mm x 25mm x 3mm for the tensile and flexural test and 100mm x 15mm x 10mm for impact test will be cut from the material. The tensile strength of the material was then measured with the use of the appropriate testing apparatus.

Table 3.2 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

3.3 Process Flowchart

The flowchart illustrates a process in which the stages are carried out in the order that they are presented. A graph that displays how a workflow or process is carried out is called a flow chart. Flowcharts may also be thought of as a graphical depiction of algorithms and the processes involved in certain jobs. On the flow chart, the phases are depicted as a variety of boxes, and the arrows connect the boxes to one another. This graphic illustrates a potential answer to a problem that has been presented. Flowcharts are often utilised in the process of planning and documenting straightforward system operations. You may have a better understanding of the process as a whole as well as each stage by consulting a flow chart. The flow of the procedure is shown in Figure 3.1, which goes all the way from the beginning to the end.

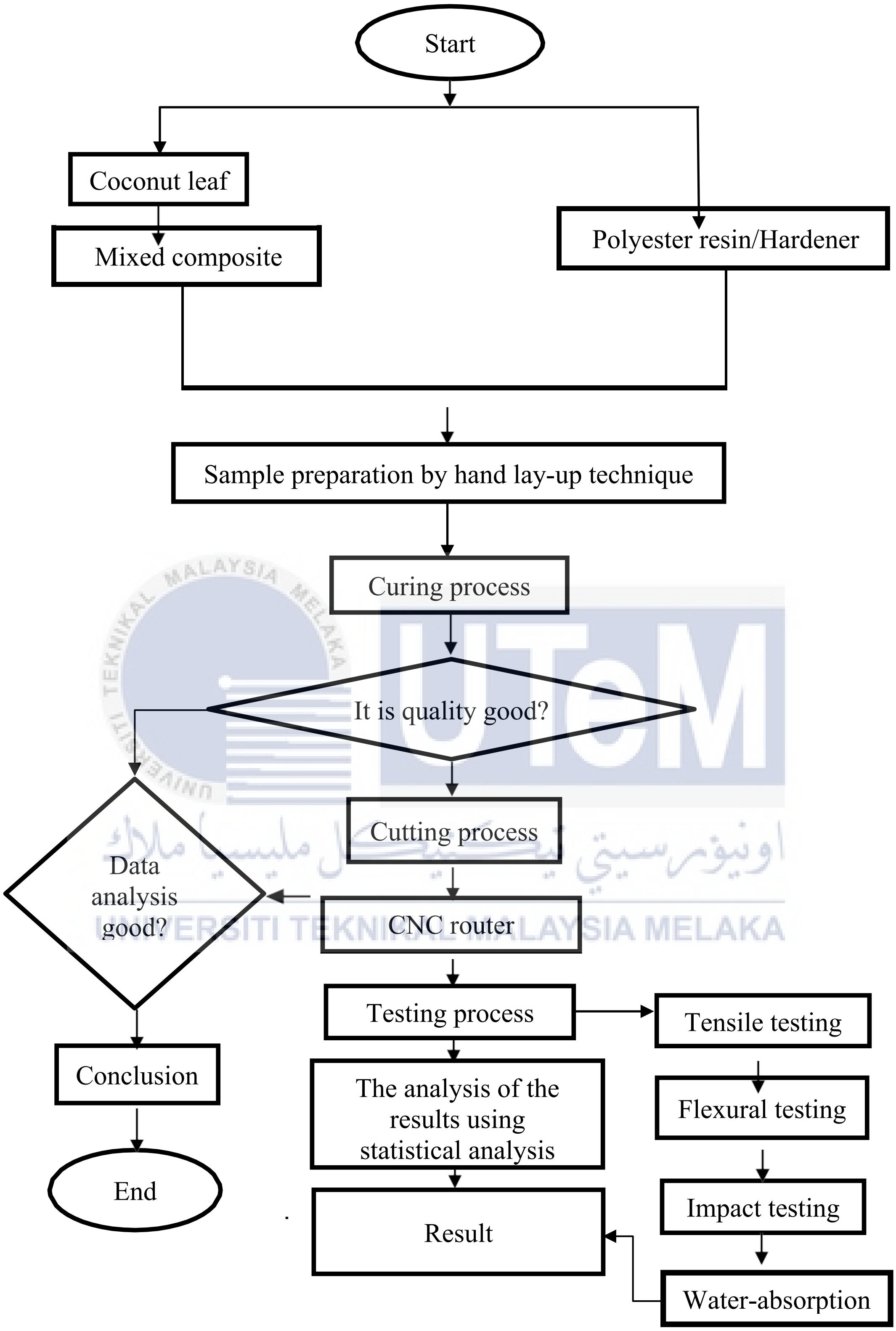


Figure 3.3 Process Flowchart

The procedures represented by the flow chart are those that were carried out successfully. From the start of the research process all the way through to its conclusion, the procedure is outlined in Figure 3.1. Before chopping it down to a certain size, the specimen, which is a coconut leaf with sandwich lamination, will first be constructed with the help of polyester resin and hardener, as this is the experimental study approach that will be used. After the materials have been refined to perfection, the process of cutting may then start.

Second, the cutting technique on the specimen is carried out with the assistance of the CNC router machine. After the specimen has been prepared to the desired level, it will then be sliced using these equipment. A CNC router machine will be used to cut the specimen, and then the total size of the specimen will be segmented into three portions for tensile testing, flexural testing, and impact testing. According to ASTM D3039, the dimensions for tensile testing are 250mm x 25mm x 3mm. ASTM D790-07 specifies the dimensions for flexural testing as 250mm x 25mm x 3mm. According to ASTM E23, the specifications for the impact tests are as follows: 100mm x 25mm x 10mm. After performing the operation of cutting on the specimen, the next step is to collect and examine the data. In the event that the data collected is inadequate, the specimen will be sliced and further data will be collected in order to get superior results

3.4 Design Material Specimen

According to Figure 3.2, the dimensions of the specimen will be 300 millimetres by 200 millimetres. After the specimen has been developed, it will be chopped down to dimensions of 250 millimetres in length and 25 millimetres in breadth in order to conduct tensile and flexural tests on it. In order to properly conduct the impact test, the specimen size will be reduced to 100 mm in length and 25 mm in breadth. In order to determine whether materials have superior properties after they have been cut, these specimens are shaped to conform to the testing criteria. In addition, specimens may be obtained in two distinct thicknesses, which are 3 millimetres (for tests of tensile and flexural strength) and 10 millimetres (for tests of impact resistance).

Figure 3.4.1 The dimension of specimen

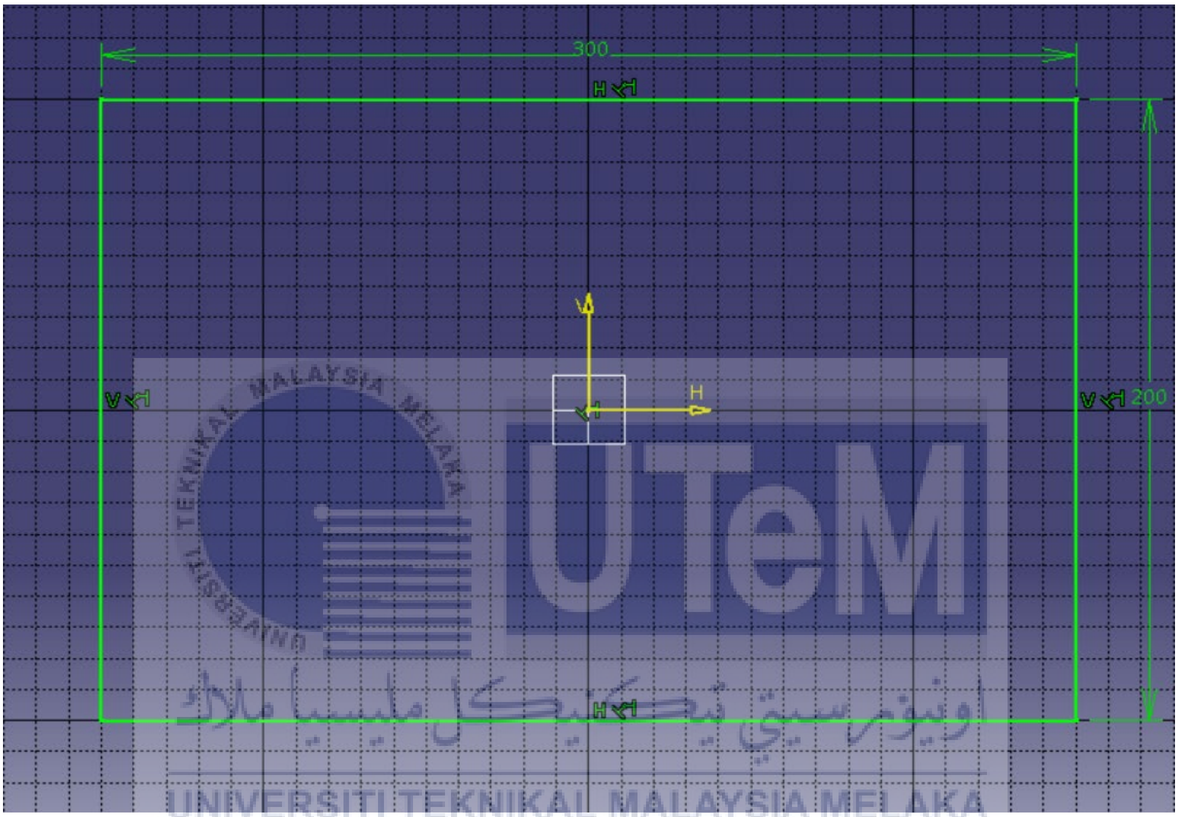


Figure 3.4.2 The dimensional design of specimens for tensile and flexural testing

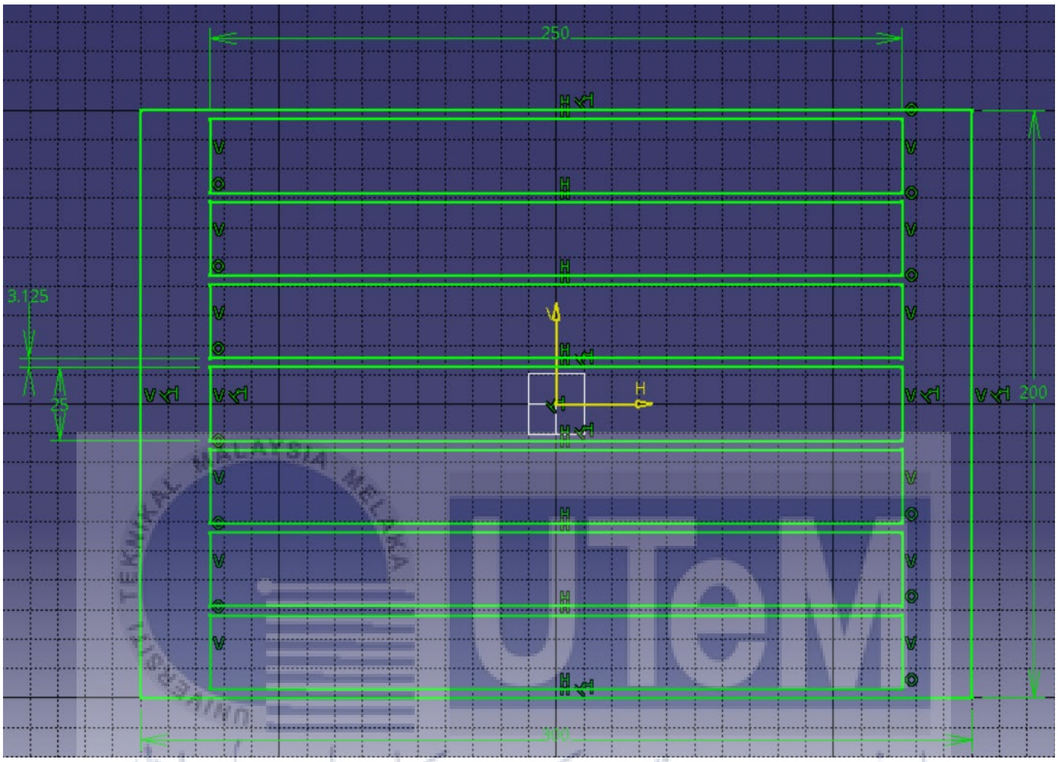
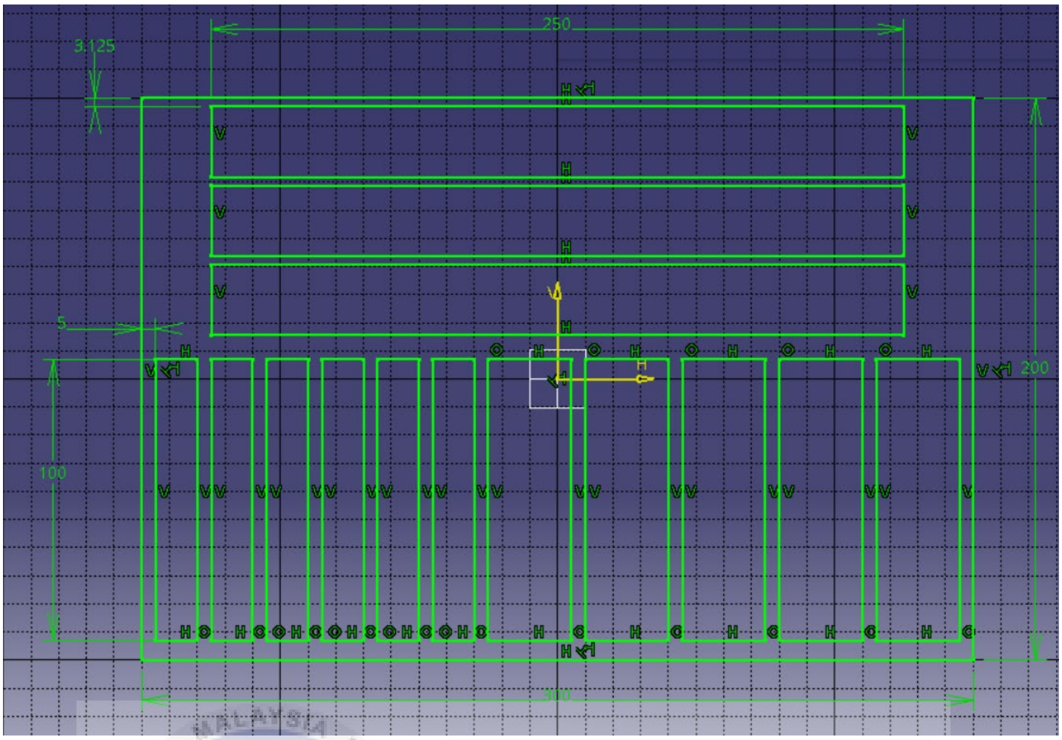


Figure 3.4.2 The dimension for flexural, impact and water absorption testing



3.5 Experimental Procedure

The experimental approach that was employed in this investigation was a procedure that involved steps for each stream. It is impossible to successfully finish the processes and activities without following these procedures. Each method requires the existence of a focal point in order to provide useful and accurate results. After that, the following section will examine a number of phases, one of which is cutting with a CNC router. Among the several processes that were used, tensile testing, flexural testing, and impact testing were some of them.

3.6 Fabricatre Material

To begin, the coconut leaf is stripped by hand from the coconut trees themselves. Before moving on to the next step, which involves washing everything with running water, the coconut leaf that is attached to the midribs has to be removed. After that, it is exposed to the sun for a few days so that any remaining moisture content in the coconut leaf may be evaporated. After the coconut leaf has been allowed to completely dehydrate, it is then chopped into smaller pieces using scissors or another type of cutting equipment so that the fragments may be easily crushed using a crusher machine. When you are finished, store the leaf powder that has been mixed in close proximity to a container that is appropriate, taking care to prevent it from coming into touch with water. After the coconut leaf has been ground into a powder, you should measure out the powder based on the thickness of the weight. Sandwiches that are constructed using reinforced material consisting of polyester resin and hardener have a specific quantity of coconut leaf powder in their construction. After then, the mixture was allowed to sit at room temperature for two days, or for forty-eight hours. The average size is used in a random fashion during the production of the composites.

Figure 3.6 The coconut leaf powder

Table 3.6 Parameter of composite ratio

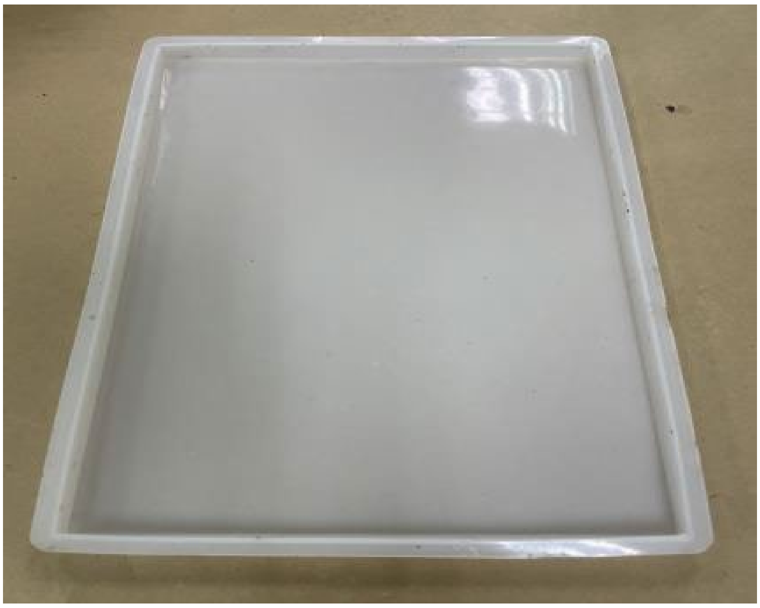
Abbreviations	Coconut Leaf Powder (%)	Weight (g)	Polyester resin (%)	Weight (g)
20CL80PR	20	6	80	226

40CL60PR	40	15	60	205
50CL50PR	50	23	50	197
60CL40PR	60	28	40	192
80CL20PR	80	33	20	187

After that, silicone is used to create the material for the mould. In order to carry out this experiment, two distinct kinds of mould were utilised. The mould for evaluating tensile and flexural strength has dimensions of 280 millimetres in length and 180 millimetres in breadth. However, the dimensions of the impact test are 180 millimetres in length and 130 millimetres in breadth. The silicone mould does not have any impact on the concoction of different chemicals.

Coconut leaf powder is used in the production of some types of sandwiches, including those that are reinforced with material that is formed of polyester resin and a hardener. Before applying the polyester resin to the mould, it was first cleaned and dried with a silicone mould release. After that, the polyester resin was applied to the mould.

Figure 3.6.2 The silicone mold of eco-friendly CLPR composites



Using the correct ratios to determine the appropriate amount of weight to assign to the coconut leaf powder. The percentages of weight for the coconut leaf powder, polyester resin, and hardener are shown in Figure 3.7. After that, a stick was used within the container that contained the mixture to ensure that the polyester resin and the hardener were thoroughly combined. Pour in the powdered coconut leaf that has previously been weighted down with the polyester resin and the hardener mixture.

Mix it up until it's completely even. After that, the liquid was put very carefully into the moulds, and then the specimen was flattened by hand using lay-up procedures before being left to dry for forty-eight hours. After the composites had been allowed to completely dry, the moulds were broken apart and the composites were removed.


Figure 3.6 The specimen before being dried at room temperature for 48 hours

3.7 CNC Router Machine

After drying up and becoming more brittle for forty-eight hours, the sample was then chopped using a computer numerically controlled (CNC) router machine. The ASTM guidelines stipulate that the sample must be sliced in a certain way. After that, the material test had to be positioned above the vice in order to secure its position. It is necessary to enter a value of zero into the position or coordinate axis on the control panel of the computer. After the coordinates have been validated in the form of an NC code, the cutting tool need to continue to be positioned in the same spot. Spindle speeds ranging from 100 to 200 rpm are typically employed. The action of pressing the "output" button on the control panel brings an end to the cutting operation.

In this experiment, three distinct kinds of ASTM standards were employed. These standards were all measured using the same method. According to ASTM D3039, the parameters for the tensile testing are as follows: 250 millimetres in length, 25 millimetres in breadth, and 3 millimetres in thickness. Second, in accordance with ASTM D790, the specifications for the flexural testing are as follows: 250 millimetres in length, 25 millimetres in breadth, and 3 millimetres in thickness. Thirdly, the parameters for the impact testing are 100 millimetres in length, 15 millimetres in breadth, and 10 millimetres in thickness as specified by ASTM E23. It is necessary to cut the samples to the dimensions that have been given. Please check that the machine is in proper working order and that the cutting tool is positioned appropriately before beginning the cutting operation. This will guarantee that the procedure is carried out successfully and that a suitable specimen size is achieved. After completely done the cutting process, it will be tested through tensile testing, flexural testing, and impact testing.

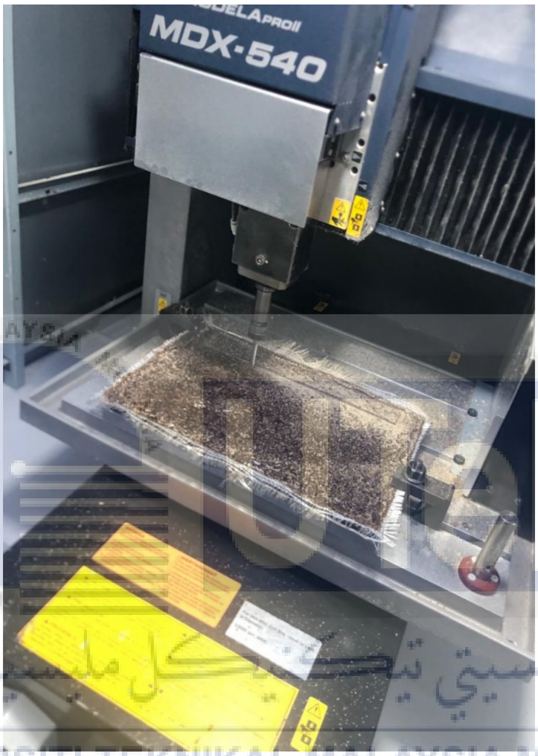


Figure 3.7 The CNC router machine MODELA PRO2 (MDX-540)

3.8 Tensile Testing Process

After the cuts have been made in the coconut leaf composites, the specimen material will be put through a tensile test using a universal testing equipment. The Universal Testing Machine model shown in Figure 3.14 is made by Shimadzu. Before commencing the tensile method, the surface of the test material should be made uniformly smooth using sandpaper using a circular motion. This might help to guarantee that the process of testing the material runs smoothly. Before commencing the tensile testing, the sample material being evaluated has to be in satisfactory condition. In tensile testing, the specimen size is ASTM 3039, which is 250 millimetres in length, 25 millimetres in breadth, and 3 millimetres in thickness, with a cross-head speed of 5 millimetres per minute. The specimen of a tensile test may be seen in figure 3.15, which was taken at the specimen grips. After the tensile operation has been completed, the results of the tensile test will be shown on the computer.

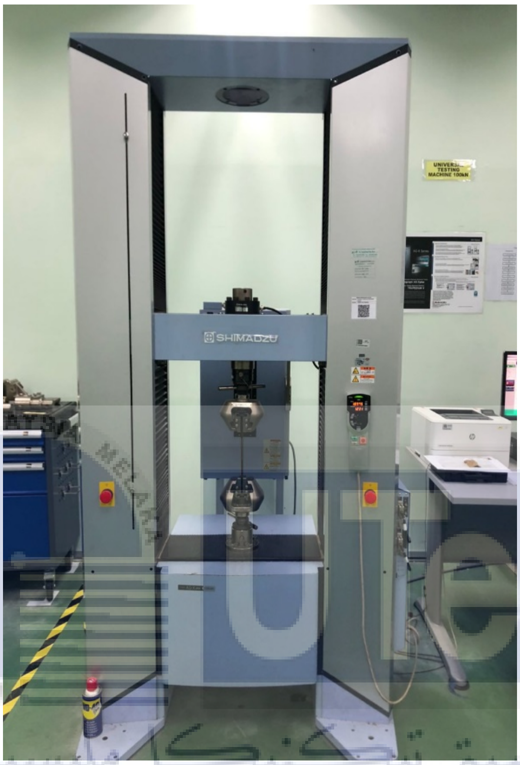


Figure 3.8.1 Universal Testing Machine model Shimadzu

Figure 3.8.2 The specimen of a tensile test

3.9 Flexural Testing Process (3-Point Bending)

The stiffness and flexural strength of a solid laminate or sandwich structure may be evaluated with the use of flexural testing, which is employed in the composites industry. A specimen made of coconut leaf that had been reinforced with polyester resin was subjected to a flexural test in which the specimen was loaded horizontally in a three-point loading arrangement. In a three-point bend test, the convex side of the sheet or plate is tensioned, and the outside fibres are put through the highest amount of stress and strain possible. Failure happens once the strain or elongation goes beyond the limitations that the material can withstand. The force is given to the middle of the specimen by the loading nose, which causes the specimen to bend in three dimensions at a predetermined pace. The maximum deflection, loading speed, and support span of this test are the parameters for this particular test. Both the ASTM and the ISO define these characteristics in a variety of different ways depending on the thickness of the test specimen. The ASTM D790 test is considered successful either when the specimen reaches a deflection of 5% or when it breaks before reaching this threshold. When the specimen breaks, the ISO 178 test is considered to have been successful. If the specimen does not break during the test, the stress state is increased to 3.5% (the usual deflection), and the test is continued for as long as is practically possible.

ASTM D790 specifies the specimen size for flexural testing as 250 millimetres in length, 25 millimetres in breadth, and 3 millimetres in thickness, with a cross-head speed of 2 millimetres per minute. The specimen that was subjected to a flexural test may be seen in Figure 3.16 resting on the supporting pins. The results of the flexural test will be shown on the computer once this process has been completed. For the flexural test, the necessary data will include the flexural stress at yield, the flexural strain at yield, the flexural stress at break, the flexural strain at break, and so on. Despite the fact that stress-strain curves and raw data are also available upon request.

3.10 Impact Testing Process

During the process of impact testing, an investigation into the various properties of the materials being tested will be carried out. A few examples of these qualities are toughness, hardness, ductility, and strength.

Before doing an analysis of the outcome data, the Charpy technique requires that the specimen have a V-notch in it. The V-notch has a diameter depth of two millimetres and an angle of forty-five degrees. The specimen size for the impact test is ASTM E23, which is 100 millimetres in length, 15 millimetres in breadth, and 10 millimetres in thickness. After finishing the process, the data pertaining to the results of the impact testing will be successfully recorded.

3.11 The Analysis of the result using the Statistical Analysis (ANOVA)

The third step is an examination of the findings via the lens of statistical methodology. On the basis of the findings of the analysis of the mechanical characteristics, we will be able to acquire the optimal ratio on coconut leaf that has been reinforced with polyester resin. The analysis of variance, often known as ANOVA, is a statistical method that is used to determine whether or not the averages of samples taken from a population are the same. The energy of the CLPR composites was analysed using a one-way analysis of variance (ANOVA), and each composite was analysed individually. Expanding ANOVA is used in this research project by calculating the energy of CLPR composites for all five environmentally friendly ratios that are either significant because the P-value is lower than the significant cut-off level, which is = 0.05. This is done so that the results may be interpreted as having a high degree of significance. It need to supply more information that may be used to choose the most effective composition for the composition material.

3.12 Summary

In a word, all of these procedures and preparations need to be carried out properly and according to the process that has been designed in order to achieve all of the project's goals. By the time this chapter is over, each and every way of planning, preparation, and planning will have played a key role in achieving the objectives and results that were sought. In conclusion, in order to obtain reliable findings from these tests, each procedure must be followed precisely, attentively, and in the exact order.

3.13 Gantt Chart

3.13.1 Gantt Chart PSM 1

As shown in Appendix A

3.13.2 Gantt Chart PSM 2

As shown in Appendix B

CHAPTER 4

RESULTS AND DISCUSSION

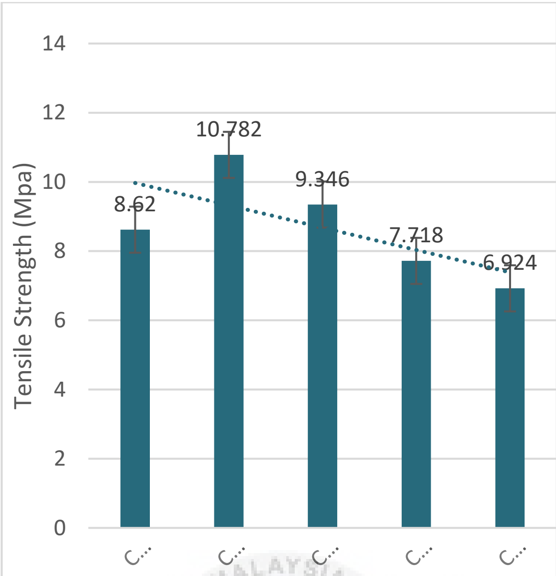
4.1 Introduction

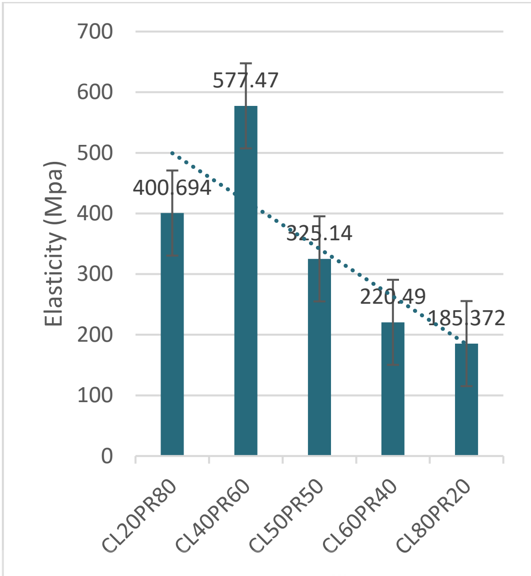
In this part, we will focus mostly on discussing the strength of composite materials. Tensile testing, flexural testing, and impact testing are the three types of testing that will be used on the CLPR composite during the testing process. This chapter will investigate and make clear the conclusions of a variety of different experiments that were carried out, as well as the computation that was applied.

4.2 Tensile Test Result

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.

It was discovered that the tensile strength and elasticity of 40CL60PR were much greater than those of the CLPR composite ratios. In comparison, the value of tensile strength and elasticity was at its lowest when looking at 80CL20PR. when a result of this discovery, it was hypothesised that the tensile strength of eco-friendly ratios of CLPR composites increases when the percentage of coconut leaf approaches around 40%. Following that, a one-way analysis of variance (ANOVA) was carried out in order to investigate the tensile strength and elasticity of the CLPR composites, the results of which are presented in Tables 4.1 and 4.2, respectively. Since the P-value is lower than the significant cut-off level, which is = 0.05, the findings presented that the tensile strength and elasticity of CLPR composites for all five eco-friendly ratios were significant. This was because the significant cut-off level is = 0.05. As a result, it was clear from the results that the tensile strength and elasticity of all five eco-friendly ratios of CLPR composites were, on average, quite distinct from one another.





(a) Tensile strength (b) Elasticity

Table 4.2.1 ANOVA of tensile strength for five eco-friendly ratios of CLPR composites

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Strength of tensile	44.3726	4	11.09315	14.00827	1.33E-05	2.866081
Error	15.838	20	0.7919			
Total	60.2106	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 α=0.05 and f = 20 degrees of freedom for error. Therefore, we have,

$$T_a = q_a(a,f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{0.7919}{5}} = 1.6874$$

As a result of the calculation, the value of Ta = 1.6874, any pairs of treatment averages that have absolute value differences that are greater than 1.6874 would indicate that the linked pair of population means is considerably different. The following are the findings of the five treatments that were averaged:

$\overline{y_{1.}}$ = 8.620 , $\overline{y_{2.}}$ = 10.782

$\overline{y_{3.}}$ = 9.346 , $\overline{y_{4.}}$ = 7.718

$\overline{y_{5.}}$ = 6.924

and the differences in averages :

$\overline{y_{1.}} - \overline{y_{2.}}$ = 8.620 – 10.782 = -2.162*

$\overline{y_{1.}} - \overline{y_{3.}}$ = 8.620 − 9.346= -0.726*

$\overline{y_{1.}} - \overline{y_{4.}}$ = 8.620 − 7.718= 0.902*

$\overline{y_{1.}} - \overline{y_{5.}}$ = 8.620 − 1.9778 = 6.6422*

$\overline{y_{2.}} - \overline{y_{3.}}$ = 10.782 − 9.346= 1.436*

$\overline{y_{2.}} - \overline{y_{4.}}$ = 10.782 − 7.718= 3.064*

$\overline{y_{2.}} - \overline{y_{5.}}$ = 10.782 − 1.9778 = 8.8042*

$\overline{y_{3.}} - \overline{y_{4.}}$ = 9.346− 7.718 = 1.628*

$\overline{y_{3.}} - \overline{y_{5.}}$ = 9.346− 1.9778 = 7.3682*

$\overline{y_{4.}} - \overline{y_{5.}}$ = 7.718 – 6.924 = 0.794*

The pair of means that have starting values that are significantly different from one another is represented by the started values. It is important to notice that the Tukey procedure demonstrates that every pair of means is distinct from one another. As a consequence of this, we are able to draw the conclusion that the difference between the mean etch rate at one power setting and the mean etch rate at other power settings.

Table 4.2.2 ANOVE of elasticity for five eco-friendly ratios of CLPR composites

ANOVA						
Source of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Elasticity c	492361.2	4	123090.3	12.52091	2.92E-05	2.866081
Error	196615.6	20	9830.781			
Total	688976.8	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 α=0.05 and f = 20 degrees of freedom for error. Therefore, we have,

$$T_a = q_a(a,f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{9830.781}{5}} = 188.007$$

As a result of the calculation, the value of Ta = 188.007, any pairs of treatment averages that have absolute value differences that are greater than 188.007 would indicate that the linked pair of population means is considerably different. The following are the findings of the five treatments that were averaged:

$\overline{y_{1.}}$ = 400.694 , $\overline{y_{2.}}$ = 577.47

$\overline{y_{3.}}$ = 325.14 , $\overline{y_{4.}}$ = 220.49

$\overline{y_{5.}}$ = 185.372

and the differences in averages :

$\overline{y_{1.}} - \overline{y_{2.}}$ = 400.694 – 577.47 = -176.776*

$\overline{y_{1.}} - \overline{y_{3.}}$ = 400.694− 325.14= -75.554*

$\overline{y_{1.}} - \overline{y_{4.}}$ = 400.694 − 220.49 = 180.204*

$\overline{y_{1.}} - \overline{y_{5.}}$ = 400.694 − 185.372 = 215.322*

$\overline{y_{2.}} - \overline{y_{3.}}$ = 577.47 − 325.14 = 252.33*

$\overline{y_{2.}} - \overline{y_{4.}}$ = 577.47 − 220.49 = 356.98*

$\overline{y_{2.}} - \overline{y_{5.}}$ = 577.47 − 185.372 = 392.098*

$\overline{y_{3.}} - \overline{y_{4.}}$ = 325.14 − 220.49 = 104.65*

$\overline{y_{3.}} - \overline{y_{5.}}$ = 325.14 − 185.372 = 139.768*

$\overline{y_{4.}} - \overline{y_{5.}}$ = 220.49 – 185.372 = 35.118*

The pair of means that have starting values that are significantly different from one another is represented by the started values. It is important to notice that the Tukey procedure demonstrates that every pair of means is distinct from one another. As a consequence of this, we are able to draw the conclusion that the difference between the mean etch rate at one power setting and the mean etch rate at other power settings.

4.3 Flexural Test Result

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.

At a cross-head speed of 2 millimetres per minute, evaluations of the mechanical properties of CLPR composite materials were carried out with testing equipment that was universal in nature. In line with the flexural testing standard established by ASTM D790-

07, the test specimens were bent in accordance with the standard. It was discovered that the maximum force and maximum stress of the 40CL60PR composite ratio were both greater than those of the CLPR composite ratios. In comparison, the highest value of force and stress for 80CL20PR was among the 50 lowest values. Based on this finding, it can be deduced that the maximum force of the environmentally friendly ratios of CLPR composites becomes more powerful when the percentage of coconut leaf is around 40%. After that, a one-way analysis of variance (ANOVA) was used to investigate the maximum force and maximum stress of the CLPR composites, the results of which are presented in Tables 4.3 and 4.4, respectively. Since the P-value is lower than the significant cut-off level, which is = 0.05, the findings showed that the maximum force and maximum stress of CLPR composites for all five eco-friendly ratios were significant. This was the case since the P-value was below the significant cut-off level. Because of this, it became clear that the average values of the maximum force and maximum stress for each of the five eco-friendly ratios of CLPR composites were distinct from one another. The combination of coconut leaf and polyester resin matrix in proportions of 40% and 60%, respectively, results in the best flexural qualities being achieved as a result of this process. In addition, the CLPR composite material for coconut leaf composition of 60% and 80% is not appropriate for the composite material since it exhibited a lower value for mechanical characteristics.

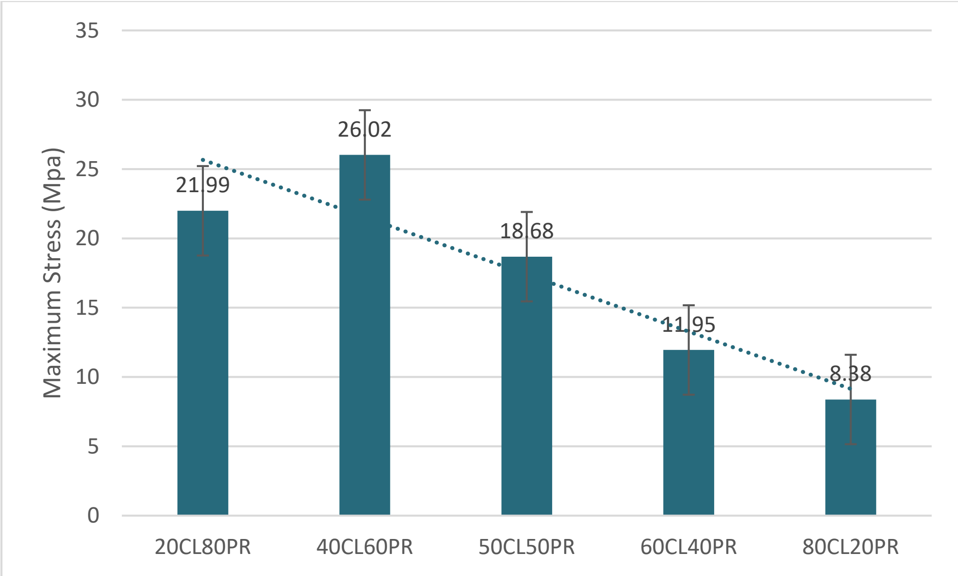


Figure 4.3 Maximum stress for five eco-friendly ratios of CLPR composite

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

ANOVA						
Source of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Strength fl	1040.618	4	260.1546	103.3465	4.62E-13	2.866081
Error	50.34608	20	2.517304			
Total	1090.965	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 α=0.05 and f = 20 degrees of freedom for error.

$$T_a = q_a(a, f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{2.517304}{5}} = 3.0085$$

As a result of the calculation, the value of Ta = 3.0085, any pairs of treatment averages that have absolute value differences that are greater than 3.0085 would indicate that the linked pair of population means is considerably different. The following are the findings of the five treatments that were averaged:

$\overline{y_{1.}}$ = 21.99 , $\overline{y_{2.}}$ = 26.02

$\overline{y_{3.}}$ = 18.68 , $\overline{y_{4.}}$ = 11.95

$\overline{y_{5.}}$ = 8.38

and the differences in averages :

$\overline{y_{1.}} - \overline{y_{2.}}$ = 21.99 – 26.02 = -4.03*

$\overline{y_{1.}} - \overline{y_{3.}}$ = 21.99 − 18.68 = 3.31*

$\overline{y_{1.}} - \overline{y_{4.}}$ = 21.99 − 11.95 = 10.04*

$\overline{y_{1.}} - \overline{y_{5.}}$ = 21.99 − 8.38 = 13.61*

$\overline{y_{2.}} - \overline{y_{3.}}$ = 26.02 − 18.68 = 7.34*

$\overline{y_{2.}} - \overline{y_{4.}}$ = 26.02 − 11.95 = 14.07*

$\overline{y_{2.}} - \overline{y_{5.}}$ = 26.02 − 8.38 = 17.64*

$\overline{y_{3.}} - \overline{y_{4.}}$ = 18.68 − 11.95 = 6.73*

$\overline{y_{3.}} - \overline{y_{5.}}$ = 18.68 − 8.38 = 10.3*

$\overline{y_{4.}} - \overline{y_{5.}}$ = 11.95 – 8.38 = 3.57*

The pair of means that have starting values that are significantly different from one another is represented by the started values. It is important to notice that the Tukey procedure demonstrates that every pair of means is distinct from one another. As a consequence of this, we are able to draw the conclusion that the difference between the mean etch rate at one power setting and the mean etch rate at other power settings.

4.4 Impact Test Result

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.

Based on this finding, it can be deduced that the energy of the environmentally friendly ratios of CLPR composites becomes more powerful when the amount of coconut leaf is somewhere about 40%. After that, a one-way analysis of variance (ANOVA) was carried out in order to evaluate the CLPR composites' total amount of energy. Because the P-value is lower than the significant cut-off 55 level, which is = 0.05, the findings showed that the energy of CLPR composites for all five eco-friendly ratios was significant. This was the case because the significant cut-off 55 level. As a result, it seemed that the average amounts of energy for each of the five environmentally acceptable ratios of CLPR composites were different. The combination of coconut leaf and polyester resin matrix in proportions of 40% and 60%, respectively, results in the best impact qualities being achieved as a result of this process.

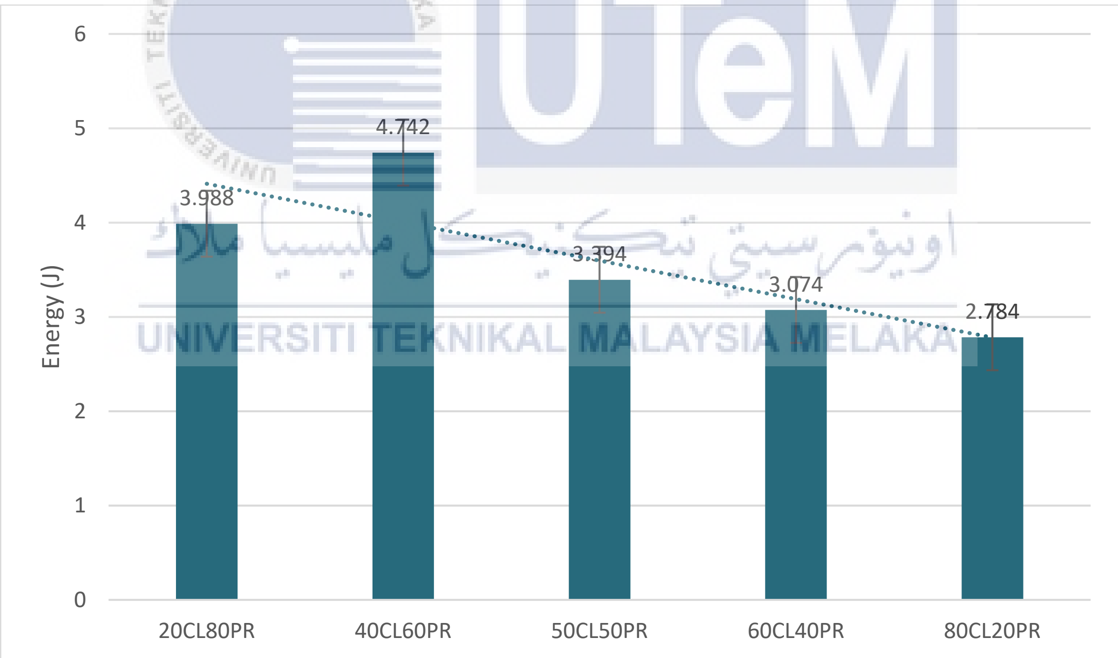


Figure 4.4 The impact strength for five eco-friendly ratios of CLPR composites.

Table 4.4 ANOVA of impact strength for five eco-friendly ratios of CLPR composites

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Strength of Impact	12.19806	4	3.049514	8.157794	0.000452	2.866081
Error	7.47632	20	0.373816			
Total	19.67438	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 α=0.05 and f = 20 degrees of freedom for error. Therefore, we have,

$$T_a = q_a(a,f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{0.3738}{5}} = 1.1593$$

As a result of the calculation, the value of Ta = 1.1593, any pairs of treatment averages that have absolute value differences that are greater than 1.1593 would indicate that the linked pair of population means is considerably different. The following are the findings of the five treatments that were averaged:

$\overline{y_{1.}}$ = 3.988 , $\overline{y_{2.}}$ = 4.742

$\overline{y_{3.}}$ = 3.394 , $\overline{y_{4.}}$ = 3.074

$\overline{y_{5.}}$ = 2.784

and the differences in averages :

$\overline{y_{1.}} - \overline{y_{2.}}$ = 3.988 – 4.742 = -0.754*

$\overline{y_{1.}} - \overline{y_{3.}}$ = 3.988 – 3.394= 0.594*

$\overline{y_{1.}} - \overline{y_{4.}}$ = 3.988 – 3.074 = 0.914*

$\overline{y_{1.}} - \overline{y_{5.}}$ = 3.988 − 2.784 = 1.204*

$\overline{y_{2.}} - \overline{y_{3.}}$ = 4.742 − 3.394 = 1.348*

$\overline{y_{2.}} - \overline{y_{4.}}$ = 4.742 − 3.074 = 1.668*

$\overline{y_{2.}} - \overline{y_{5.}}$ = 4.742 − 2.784 = 1.958*

$\overline{y_{3.}} - \overline{y_{4.}}$ = 3.394 − 3.074 = 0.32*

$\overline{y_{3.}} - \overline{y_{5.}}$ = 3.394 − 2.784 = 0.61*

$\overline{y_{4.}} - \overline{y_{5.}}$ = 3.074 – 2.784 = 0.29*

The pair of means that have starting values that are significantly different from one another is represented by the started values. It is important to notice that the Tukey procedure demonstrates that every pair of means is distinct from one another. As a consequence of this, we are able to draw the conclusion that the difference between the mean etch rate at one power setting and the mean etch rate at other power settings.

4.5 Water Absorption Test Result

The purpose of a Water Absorption Test is to ascertain the quantity of water that a substance can absorb under specific conditions. The test findings yield significant data regarding the material's porosity, permeability, and durability, which are crucial parameters for evaluating its appropriateness for different applications.

The figure below illustrates the absorption rates of water for various combinations of coconut leaf and polymer. An intriguing discovery was made that the composite mixture consisting of 80%CL and 20%PR exhibited the highest water absorption capacity. Conversely, the material composed of 20%CL and 80%PR exhibited the lowest water absorption. According to this discovery, it was determined that the water absorption rates in CLPR composites decrease as the plasticity level increases up to 80%. This demonstrates that the ratio of composition directly impacts the water absorption capabilities of these composites.

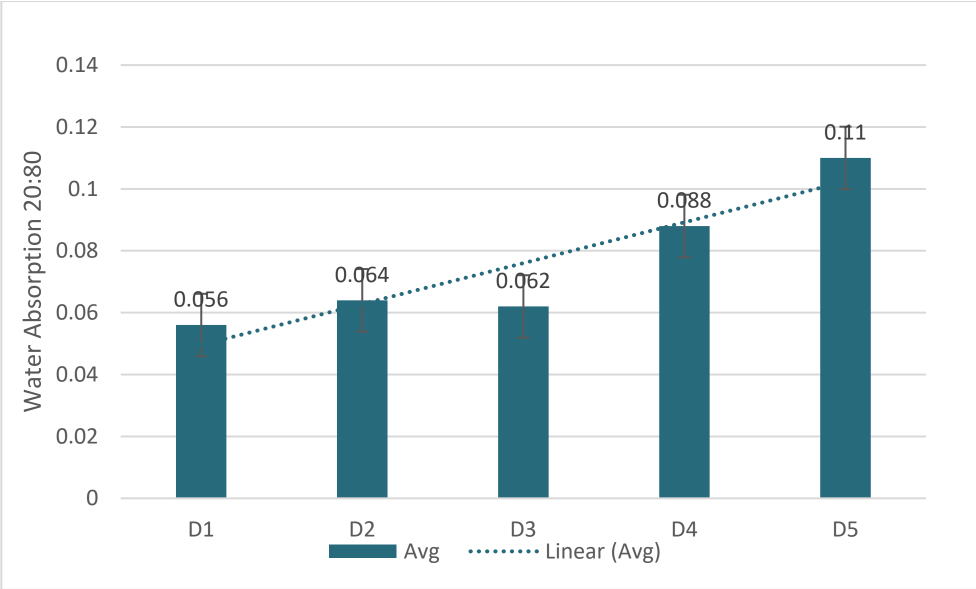


Figure 4.5.1 Water Absorption for ratio 20CL80PR composite

Table 4.5.1 ANOVA of Water Absorption for ratio 20CL80PR composite

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.01224	4	0.00306	9.807692	6.51E-05	2.75871
Within Groups	0.0078	25	0.000312			
Total	0.02004	29				

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 α=0.05 and f = 20 degrees of freedom for error. Therefore, we have,

$$T_a = q_a(a, f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{0.000312}{5}} = 0.0335$$

As a result of the calculation, the value of Ta = 0.0335, any pairs of treatment averages that have absolute value differences that are greater than 0.0335 would indicate that the linked pair of population means is considerably different. The following are the findings of the five treatments that were averaged:

$\overline{y_{1.}}$ = 0.056 , $\overline{y_{2.}}$ = 0.064

$\overline{y_{3.}}$ = 0.062 , $\overline{y_{4.}}$ = 0.088

$\overline{y_{5.}}$ = 0.11

and the differences in averages :

$\overline{y_{1.}} - \overline{y_{2.}}$ = 0.056 – 0.064 = -0.008*

$\overline{y_{1.}} - \overline{y_{3.}}$ = 0.056 – 0.062 = -0.006*

$\overline{y_{1.}} - \overline{y_{4.}}$ = 0.056 – 0.088 = -0.032*

$\overline{y_{1.}} - \overline{y_{5.}}$ = 0.056 – 0.11 = 0.054*

$\overline{y_{2.}} - \overline{y_{3.}}$ = 0.064 – 0.062 = 0.002*

$\overline{y_{2.}} - \overline{y_{4.}}$ = 0.064 – 0.088 = -0.024*

$\overline{y_{2.}} - \overline{y_{5.}}$ = 0.064 – 0.11 = -0.046*

$\overline{y_{3.}} - \overline{y_{4.}}$ = 0.062 – 0.088 = -0.026*

$\overline{y_{3.}} - \overline{y_{5.}}$ = 0.062 – 0.11 = -0.048*

$\overline{y_{4.}} - \overline{y_{5.}}$ = 0.088 – 0.11 = -0.022*

The pair of means that have starting values that are significantly different from one another is represented by the started values. It is important to notice that the Tukey procedure demonstrates that every pair of means is distinct from one another. As a consequence of this, we are able to draw the conclusion that the difference between the mean etch rate at one power setting and the mean etch rate at other power settings.

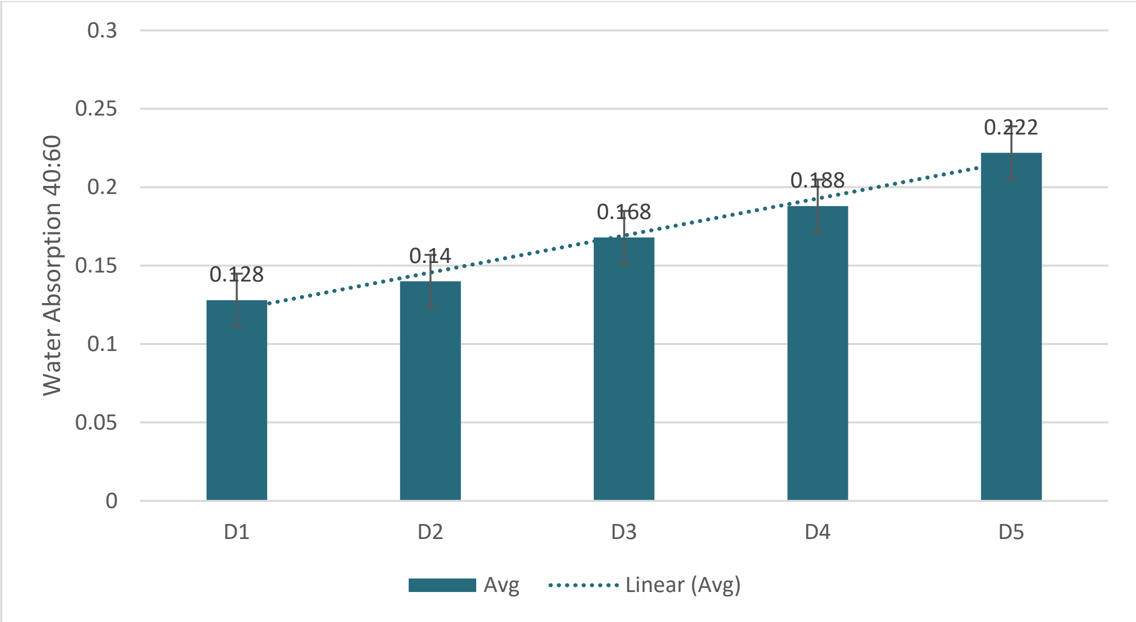


Figure 4.5.2 Water Absorption for ratio 40CL60PR composite

Table 4.5.2 ANOVA of Water Absorption for ratio 40CL60PR composite

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.028464	4	0.007116	15.60526	6.07E-06	2.866081
Within Groups	0.00912	20	0.000456			
Total	0.037584	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 α=0.05 and f = 20 degrees of freedom for error. Therefore, we have,

$$T_a = q_a(a,f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{0.000456}{5}} = 0.0405$$

As a result of the calculation, the value of Ta = 0.0405, any pairs of treatment averages that have absolute value differences that are greater than 0.0405 would indicate that the linked pair of population means is considerably different. The following are the findings of the five treatments that were averaged:

$\overline{y_{1.}} = 0.128$, $\overline{y_{2.}} = 0.14$

$\overline{y_{3.}} = 0.168$, $\overline{y_{4.}} = 0.188$

$\overline{y_{5.}} = 0.222$

and the differences in averages :

$\overline{y_{1.}} - \overline{y_{2.}} = 0.128 - 0.14 = -0.012*$

$\overline{y_{1.}} - \overline{y_{3.}} = 0.128 - 0.168 = -0.04*$

$\overline{y_{1.}} - \overline{y_{4.}} = 0.128 - 0.188 = -0.06*$

$\overline{y_{1.}} - \overline{y_{5.}} = 0.128 - 0.222 = 0.094*$

$\overline{y_{2.}} - \overline{y_{3.}} = 0.14 - 0.168 = -0.028*$

$\overline{y_{2.}} - \overline{y_{4.}} = 0.14 - 0.188 = -0.048*$

$\overline{y_{2.}} - \overline{y_{5.}} = 0.14 - 0.222 = -0.082*$

$\overline{y_{3.}} - \overline{y_{4.}} = 0.168 - 0.188 = -0.02*$

$\overline{y_{3.}} - \overline{y_{5.}} = 0.168 - 0.222 = -0.054*$

$\overline{y_{4.}} - \overline{y_{5.}} = 0.188 - 0.222 = -0.034*$

The pair of means that have starting values that are significantly different from one another is represented by the started values. It is important to notice that the Tukey procedure demonstrates that every pair of means is distinct from one another. As a consequence of this, we are able to draw the conclusion that the difference between the mean etch rate at one power setting and the mean etch rate at other power settings.

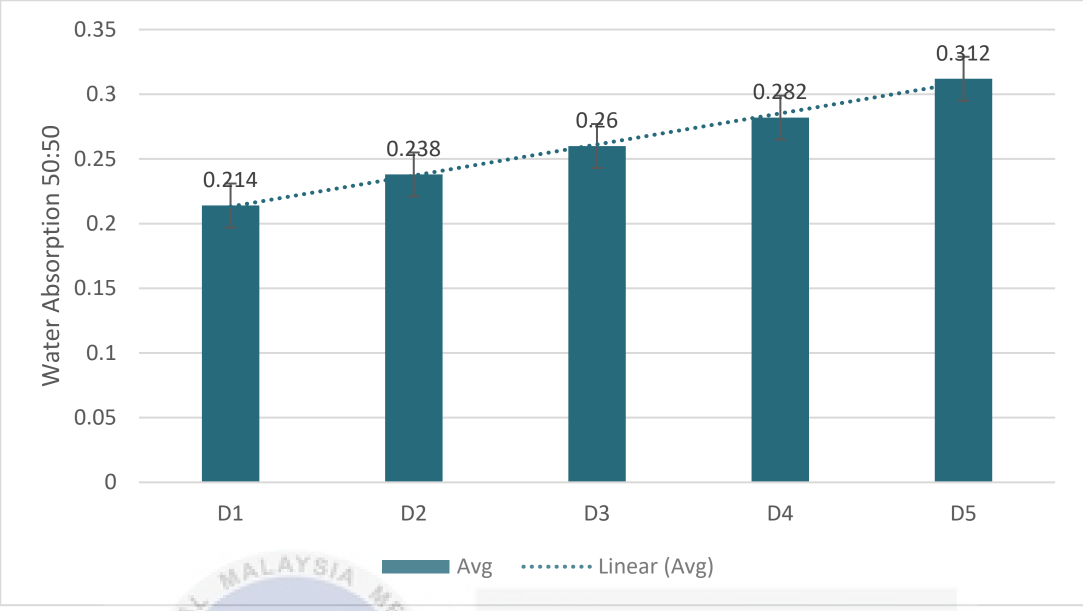


Figure 4.5.3 Water absorption for ratio 50CL50PR composite

Table 4.5.3 ANOVA of Water Absorption for ratio 50CL50PR composite

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.028904	4	0.007226	21.3787	5.45E-07	2.866081
Within Groups	0.00676	20	0.000338			
Total	0.035664	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 α=0.05 and f = 20 degrees of freedom for error. Therefore, we have,

$$T_a = q_a(a, f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5{,}20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{0.000338}{5}} = 0.0349$$

As a result of the calculation, the value of Ta = 0.0349, any pairs of treatment averages that have absolute value differences that are greater than 0.0349 would indicate that the linked pair of population means is considerably different. The following are the findings of the five treatments that were averaged:

$\overline{y_{1.}} = 0.214$, $\overline{y_{2.}} = 0.238$

$\overline{y_{3.}} = 0.26$, $\overline{y_{4.}} = 0.282$

$\overline{y_{5.}} = 0.312$

and the differences in averages :

$\overline{y_{1.}} - \overline{y_{2.}} =$ 0.214 – 0.238 = -0.024*

$\overline{y_{1.}} - \overline{y_{3.}} =$ 0.214 – 0.26 = -0.046*

$\overline{y_{1.}} - \overline{y_{4.}} =$ 0.214 – 0.282 = -0.068*

$\overline{y_{1.}} - \overline{y_{5.}} =$ 0.214 – 0.312 = -0.098*

$\overline{y_{2.}} - \overline{y_{3.}} =$ 0.238 – 0.26 = -0.022*

$\overline{y_{2.}} - \overline{y_{4.}} =$ 0.238 – 0.282 = -0.044*

$\overline{y_{2.}} - \overline{y_{5.}} =$ 0.238 – 0.312 = -0.074*

$\overline{y_{3.}} - \overline{y_{4.}} =$ 0.26 – 0.282 = -0.022*

$\overline{y_{3.}} - \overline{y_{5.}} =$ 0.26 – 0.312 = -0.052*

$\overline{y_{4.}} - \overline{y_{5.}} =$ 0.282 – 0.312 = -0.03*

The pair of means that have starting values that are significantly different from one another is represented by the started values. It is important to notice that the Tukey procedure demonstrates that every pair of means is distinct from one another. As a consequence of this, we are able to draw the conclusion that the difference between the mean etch rate at one power setting and the mean etch rate at other power settings.

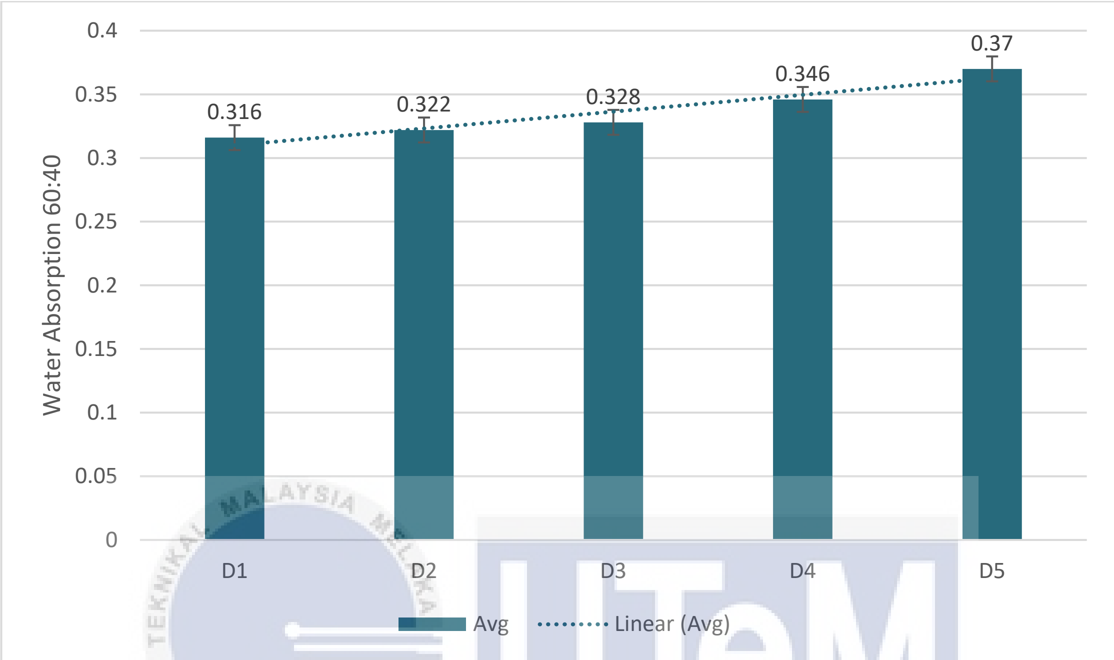


Figure 4.5.4 Water absorption for ratio 60CL40PR composite

Table 4.5.4 ANOVA of Water Absorption for ratio 60CL40PR composite

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.009576	4	0.002394	3.520588	0.024847	2.866081
Within Groups	0.0136	20	0.00068			
Total	0.023176	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 α=0.05 and f = 20 degrees of freedom for error. Therefore, we have,

$$T_a = q_a(a,f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5,20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{0.00068}{5}} = 0.0494$$

As a result of the calculation, the value of Ta = 0.0494, any pairs of treatment averages that have absolute value differences that are greater than 0.0494 would indicate that the linked pair of population means is considerably different. The following are the findings of the five treatments that were averaged:

$\overline{y_{1.}}$ = 0.316 , $\overline{y_{2.}}$ = 0.322

$\overline{y_{3.}}$ = 0.328 , $\overline{y_{4.}}$ = 0.346

$\overline{y_{5.}}$ = 0.37

and the differences in averages :

$\overline{y_{1.}} - \overline{y_{2.}}$ = 0.316 – 0.322 = -0.006*

$\overline{y_{1.}} - \overline{y_{3.}}$ = 0.316 – 0.328 = -0.012*

$\overline{y_{1.}} - \overline{y_{4.}}$ = 0.316 – 0.346 = -0.03*

$\overline{y_{1.}} - \overline{y_{5.}}$ = 0.316 – 0.37 = -0.054*

$\overline{y_{2.}} - \overline{y_{3.}}$ = 0.322 – 0.328 = -0.006*

$\overline{y_{2.}} - \overline{y_{4.}}$ = 0.322 – 0.346 = -0.024*

$\overline{y_{2.}} - \overline{y_{5.}}$ = 0.322 – 0.37 = -0.048*

$\overline{y_{3.}} - \overline{y_{4.}}$ = 0.328 – 0.346 = -0.018*

$\overline{y_{3.}} - \overline{y_{5.}}$ = 0.328 – 0.37 = -0.042*

$\overline{y_{4.}} - \overline{y_{5.}}$ = 0.346 – 0.37 = -0.024*

The pair of means that have starting values that are significantly different from one another is represented by the started values. It is important to notice that the Tukey procedure demonstrates that every pair of means is distinct from one another. As a consequence of this, we are able to draw the conclusion that the difference between the mean etch rate at one power setting and the mean etch rate at other power settings.

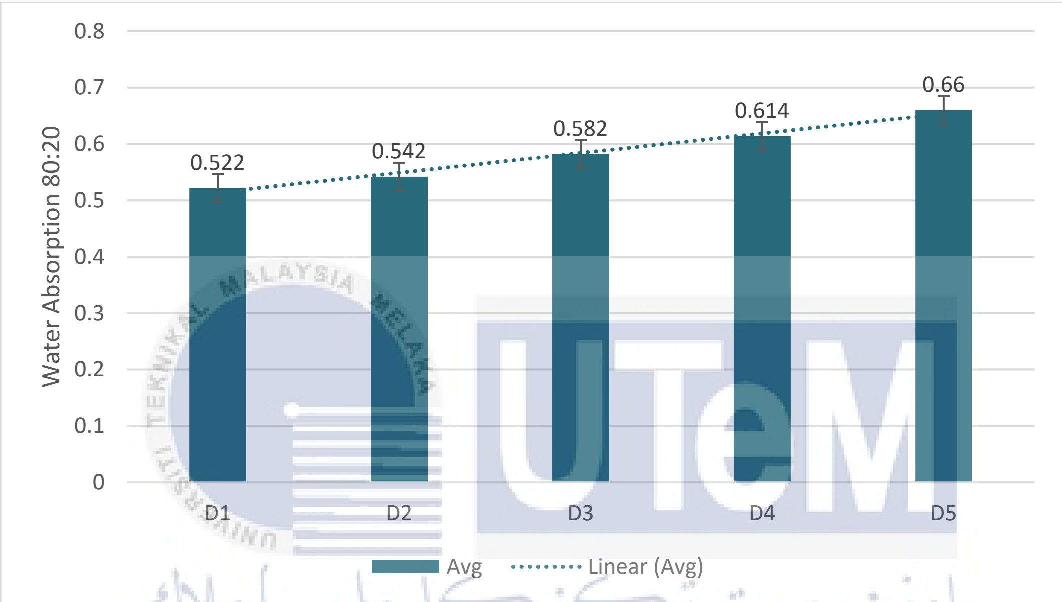


Figure 4.5.5 Water absorption for ratio 80CL20PR composite

Table 4.5.5 ANOVA of Water Absorption for ratio 80CL20PR composite

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.06144	4	0.01536	9.264174	0.00021	2.866081
Within Groups	0.03316	20	0.001658			
Total	0.0946	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 α=0.05 and f = 20 degrees of freedom for error. Therefore, we have,

$$T_a = q_a(a, f)\sqrt{\frac{MS_E}{n}} = q_{0.05}(5{,}20)\sqrt{\frac{MS_E}{n}} = 4.24\sqrt{\frac{0.0017}{5}} = 0.0782$$

As a result of the calculation, the value of Ta = 0.0782, any pairs of treatment averages that have absolute value differences that are greater than 0.0782 would indicate that the linked pair of population means is considerably different. The following are the findings of the five treatments that were averaged:

$\overline{y_{1.}}$ = 0.522 , $\overline{y_{2.}}$ = 0.542

$\overline{y_{3.}}$ = 0.582 , $\overline{y_{4.}}$ = 0.614

$\overline{y_{5.}}$ = 0.66

and the differences in averages :

$\overline{y_{1.}} - \overline{y_{2.}}$ = 0.522 – 0.542 = -0.002*

$\overline{y_{1.}} - \overline{y_{3.}}$ = 0.522 – 0.582 = -0.006*

$\overline{y_{1.}} - \overline{y_{4.}}$ = 0.522 – 0.614 = -0.092*

$\overline{y_{1.}} - \overline{y_{5.}}$ = 0.522 – 0.66 = -0.138*

$\overline{y_{2.}} - \overline{y_{3.}}$ = 0.542 – 0.582 = -0.04*

$\overline{y_{2.}} - \overline{y_{4.}}$ = 0.542 – 0.614 = -0.072*

$\overline{y_{2.}} - \overline{y_{5.}}$ = 0.542 – 0.66 = -0.118*

$\overline{y_{3.}} - \overline{y_{4.}}$ = 0.582 – 0.614 = -0.032*

$\overline{y_{3.}} - \overline{y_{5.}}$ = 0.582 – 0.66 = -0.078*

$\overline{y_{4.}} - \overline{y_{5.}}$ = 0.614 – 0.66 = -0.046*

The pair of means that have starting values that are significantly different from one another is represented by the started values. It is important to notice that the Tukey procedure demonstrates that every pair of means is distinct from one another. As a consequence of this, we are able to draw the conclusion that the difference between the mean etch rate at one power setting and the mean etch rate at other power settings.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

In this chapter, a summary of the experiment's results and suggestions for future research are provided. Utilizing three distinct testing procedure such as tensile testing, flexural testing, impact testing, and water absorption as the objective of this study was to collect more information regarding how to preserve a high-quality, strong material on composites made from coconut leaf.

5.2 Conclusion

There are three objectives that need to be accomplished in order to properly complete this research. A composite material that is manufactured with filler components such as waste coconut leaf reinforced polyester resin has certain mechanical qualities. A mixture of twenty percent CL and eighty percent polyester resin, forty percent CL and sixty percent polyester resin, fifty percent CL and fifty percent polyester resin, sixty percent CL and forty percent polyester resin, and eighty percent CL and twenty percent polyester resin volume of CLPR composite was blended to create the specimen. The tensile test, the flexural test, and the impact test of the CLPR composite were all successful in their examination of the mechanical characteristics of the material, and as a result, everything has been archived through this experiment. In order to explore the mechanical properties of coconut leaf that has been reinforced with polyester resin, tensile, flexural, and impact tests have been usefully utilized. In accordance with the ASTM standard, all specimens are subjected to tensile testing, flexural testing, and impact testing each and every time. Additionally, the specimen was brought into existence by the utilization of the hand lay-up procedure. It is of the utmost importance to verify that the specimen was brought into existence using components of superior quality. It was discovered that the tensile strength and elasticity of 40CL60PR were found to be higher than the CLPR composite ratios, which are tensile strength (10.782 MPa) and elasticity (577.47 MPa). This was determined based on the previous result, which demonstrates that the tensile strength exceeds the elasticity. The tensile strength of the eco-friendly ratios of CLPR composites was found to increase as the proportion of coconut leaf increased to approximately forty percent, according to this observation. The tensile strength and elasticity of the CLPR composites were then analyzed using a one-way analysis of variance (ANOVA), which was applied to the data.

The maximum stress of 40CL60PR were found to be higher than those of the CLPR composite ratios, with the maximum stress 26.02 MPa. This was discovered during the flexural testing test. In comparison, the maximum stress (8.38 MPa) values for 80CL20PR were the lowest of any material. Due to the fact that the P-value is lower than the significant cut-off threshold, which is $\alpha = 0.05$, the results demonstrated that the maximum force and maximum stress exerted by CLPR composites for all five eco-friendly ratios were significant. All of the maximum force and maximum stress for the five eco-friendly ratios of CLPR composites were found to have distinct averages, as a result of this conclusion. In addition to that, this indicates that the percentage of coconut leaf with 40% and polyester resin with 60% becomes stronger than the other ratios of CLPR composites accordingly that are used.

In comparison to the other environmentally friendly ratios of CLPR composites, the coconut leaf reinforced polyester resin with a percentage of polyester resin 60% and coconut leaf 40% has a higher energy (4.742 Joule) than the other ratios. This was determined by impact testing. Considering the results of the analysis of variance (ANOVA), it is possible to draw the conclusion that the impact strength of five eco-friendly ratios of CLPR composites was significant. The combination of coconut leaf and polyester resin matrix in proportions of forty percent and sixty percent, respectively, yields the best impact qualities. This is the last factor to be considered.

For the water absorption testing, the coconut leaf reinforced polyester resin with a percentage of polyester resin 20% and coconut leaf 80% has a higher absorption (0.66) than the other ratios. Considering the results of the analysis of variance (ANOVA), it is possible to draw the conclusion that the water absorption of five eco-friendly ratios of CLPR composites was significant. The combination of coconut leaf and polyester resin matrix in proportions of eighty percent and twenty percent, respectively, has the best absorption qualities. This is the last factor to be considered.

5.3 Recommendation

To enhance future research, it is advisable to incorporate additional mechanical testing, such as compression tests, in order to thoroughly examine and analyze the various mechanical properties of CLPR composites. Furthermore, conduct thermal analysis, such as Differential Scanning Calorimetry (DSC) or Thermogravimetric Analysis (TGA), to understand the material's thermal stability, decomposition temperature, and heat absorption characteristics. This can be crucial for applications in environments with varying temperature conditions.. To enhance the results of future study, it is recommended to include a wider range of weight percentages for the reinforcement values.

5.4 Project Potential

There are a lot of possible uses for the composite strengthening of coconut leaf fibers with polyester and fiberglass that this research is investigating. Create eco-friendly, lightweight construction materials with composites as one example. Potential long-lasting and eco-friendly substitutes for conventional building materials could be made by combining fibers from coconut leaves with fiberglass and polyester. Beyond that, we can investigate potential applications of the material in the production of car parts. Because of its natural fibers and relatively low density, this material may provide an optimal trade-off between weight and strength, which could improve fuel economy.

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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																

APPENDIX BGantt 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 experimen	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 submission draft PSM 2	Plan																
	Actual																
Second submisson draft PSM 2	Plan																
	Actual																
Submission Full report psm2	Plan																
	Actual																
Make a correction of full report	Plan																
	Actual																