DESIGN OF KENAF FIBER POLYMER COMPOSITE FOR INTERIOR CAR DOOR PANEL APPLICATION

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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LIST OF ABBREVIATIONS

NFPC	Natural Fiber Polymer Composite
KFPC	Kenaf Fiber Polymer Composite
UTM	Universal Testing Machine
ASTM	American Society for Testing and Materials
LKTN	Lembaga Kenaf dan Tembakau Negara
UTS	Ultimate Tensile Strength

ABSTRACT (BM)

Sejak kebelakangan ini, serat semulajadi telah menjadi tumpuan para penyelidik, jurutera dan saintis sebagai bahan pengukuhan alternatif yang digunakan dalam menghasilkan komposit polimer terutamanya dalam industri automotif. Dalam industri automotif, penggunaan serat semulajadi mempunyai banyak kelebihan berbanding dengan gentian sintetik seperti mempunyai kos yang rendah, rintangan kepada lelasan, boleh dikitar semula, boleh diperbaharui dan meningkatkan kecekapan. Walau bagaimanapun, banyak komposit serat semulajadi yang ada dipasaran tidak direka untuk kegunaan khusus menyebabkan sifat mekanikal komposit tersebut tidak sesuai digunakan dalam komponen automotif seperti panel pintu dalaman. Projek ini bertujuan untuk mengkaji dan menghasilkan komposit serat kenaf untuk digunakan sebagai panel pintu dalaman di dalam industri automotif. Susunan serat kenaf di dalam komposit akan mempengaruhi sifat mekanikal seperti kekuatan tegangan dan kekuatan lenturan telah dikaji dalam projek ini. Serat kenaf disusun secara rawak dan lurus (0°) sebelum proses seperti meratakan resin dan pembungkusan vakum untuk menghasilkan sampel komposit. Selepas itu, ujian tegangan dan lenturan dijalankan ke atas sampel komposit mengikut piawaian ASTM yang ditetapkan. Dalam kajian ini, didapati bahawa kehadiran serat kenaf telah meningkatkan kekuatan tegangan dan kekuatan lenturan komposit dengan memindahkan beban antara serat dan memberikan komposit bentuk akhirnya. Selain itu, serat kenaf yang disusun lurus meningkatkan sifat mekanikal seperti kekuatan tegangan dan lenturan dengan lebih banyak berbanding serat kenaf yang disusun secara rawak. Hal ini kerana serat kenaf yang disusun lurus mempunyai nisbah aspek yang baik dan serat yang sejajar memindahkan tekanan secara sama rata diantar helaian serat.

ABSTRACT (BI)

Recently, natural fibers have gained popularity among researchers, engineers, and scientists as alternative reinforcing materials used in manufacturing polymer composites, especially in the automotive industry. In the automotive industry, the use of natural fibers provides many advantages over synthetic conventional components such as low cost, low density, abrasion resistance, recyclability, renewability, and eco-efficiency. However, many natural fiber composites available today are not designed for one specific application cause the mechanical properties of the composites are not suitable to use in certain automotive components such as inner door panels. This project aims to study and fabricate the kenaf fiber composite to use as an inner door panel in an automotive application. The effects of kenaf fibers orientation in the composites on the mechanical properties such as tensile and flexural strength were investigated in this project. Kenaf fibers were arranged in random orientation and unidirectional (0°) orientation before it undergoes the hand layup and vacuum bagging process to produce the composite samples. After that, tensile and flexural tests were done on the composite samples following the designated ASTM standards. In this study, it was found that the presence of kenaf fibers were increasing the tensile strength and flexural strength of the composite by transferring loads between fibers and giving the composite its net shape. In addition, for the natural fiber orientation, the unidirectional orientation of kenaf fibers can drastically increase the tensile and flexural strength of the composite compared to the random orientation of kenaf fibers. The unidirectional orientation increases mechanical properties because of its aspect ratio is good enough and the fibers are aligned making the load can transfer equally between the fibers.

CHAPTER 1

INTRODUCTION

1.1 Project Overview

Fibers are threads of material that resemble hair and look as continuous filaments [1]. Synthetic and natural fibers are the two types of fiber. Synthetic fibers are fibers made by human through chemical synthesis and synthesized polymers of small molecules. Synthetic fibers made form the compound of raw materials such as petroleum-based chemicals that polymerized into a chemical bonds two adjacent carbon atoms. Fibers obtained from natural sources are derived from geological processes or animals and plants. A natural fiber can be used in composite materials in which the orientation of the fiber affects the properties. Natural fibers are classified into three types: cellulose-based, protein-based, and mineral-based fibers [2]. Natural fiber compositions can be classified into three basic components: cellulose, hemicellulose, and lignin. Natural fibers are made up of a variety of elements including cellulose, lignin, pectin, and other materials, giving them distinct physical and chemical properties [3]. Composites made from high-strength natural fibers mixed with polymers are called natural fiber polymer composites (NFPC). Natural fibers that can work with polymer composites include kenaf, jute, hemp, sugar palm, coir, cotton, bamboo, oil palm, pineapple leaf, and banana stem [4]. Natural fiber composites are eco-friendly materials that have gotten a lot of attention in the product production engineering industry.

The properties of Natural Fiber Polymer Composite (NFPC) depend on several factors like orientation of natural fiber, volume fraction of the composites, application of chemical treatment and manufacturing process. These factors can influence the mechanical properties of NFPC like tensile strength, flexural strength, fatigue resistance, fracture toughness and impact resistance. The orientation of the fibers is crucial in determining the composite's mechanical properties. Mechanical properties alter noticeably when the angle of orientation changes from 0 to 90 degrees [5]. The angle of orientation was also shown to affect the damping properties of composites. Chemical treatment on the natural fiber can modifying the fiber surface properties so the poor compatibility between fiber and matrix can be ignored [6]. The surface and strength of fibers can be enhanced by chemically treating them to improve adhesion to polymer matrixes. There are a number of different processes used to fabricate composite materials, and each process is applicable to a particular material. The manufacturing processes that can be used to produce natural fiber polymer composites are hand layup, spray-up, vacuum bag moulding, resin transfer moulding, vacuum infusion, compression moulding, injection moulding and etc. The efficiency of a manufacturing processes depends on the type and volume of matrix material used, because each material has its own physical properties, such as melting point, stiffness, tensile strength, flexural strength and interlaminar shear strength. As a result, manufacturing processes are defined based on the material used.

The initial phase in the manufacturing process is design; several crucial decisions must be taken at this point that will affect the final product [2]. As a result, various factors must be considered early in the design process, including manufacture, assembly, cost, sales, maintenance, disposal, and recycling. Natural fiber composite product design follows the same principles as other product design methods. Designers require three things: material, machinery, and manufacturing methods. This means that designers are responsible not only for creating high-quality designs, but also for suggesting and choosing acceptable materials so that the product may be manufactured at a reasonable cost. In this final year project, natural fiber polymer composite will be designed and fabricated for the used in automotive application such as interior door panel using several manufacturing process and chemical treatment. The intended application of this fiber composite requires the following material properties: uniform composite composition, anisotropic, good fracture toughness, and etc. The mechanical behavior of the composite will be quantified using testing equipment that include tensile strength, flexural strength and interlaminar shear strength.

In the design of future vehicles, bio-composite will play a major role in reducing their weight and emissions, which will lead to a savings of 250 million barrels of crude oil for each 25% reduction in vehicle weight [7]. Doors, seatbacks, headliners, package trays, dashboards, and interior parts made from natural fiber composites have been adopted by European car manufacturers and suppliers. Composites reinforced with natural fibers are used primarily as low-cost materials for various applications including vehicle interior linings. The automotive industry has renewed interest in natural fibers, particularly as a glass fiber substitute. As the automotive industry recognizes its significance, it improves the recyclability of new products and develops bio-based products, especially for the vehicle's body, in order to reduce weight. Fig. 1.1 shows example of bio-based car door inner panel that been processed using natural fiber blending with thermoplastic matrix. The car door inner panel is manufactured by hot press process that curing the resin such as epoxy or polyurethane resins under heat before using it to coated non-woven based on natural fibers.

Figure 1.1: Example of bio-based car door inner panel [7]

1.2 Problem Statement

Natural fiber polymer composites are applied in the automotive industry by requiring certain material properties, such as uniform composition, synergistic properties, high fracture toughness, high rigidity, good thermal and sound insulation, etc... There is a problem with many fiber composites available now because they are not designed for one specific application, so their properties will not completely meet the needs of the part. The fiber composites can be easily designed, if the designed composites are limited to only one application, such as automotive, in terms of how the fiber and polymer are used, the treatment process, the fiber orientation, etc. In addition, the use of natural fiber make the automotive industry more sustainable because they are not hazardous and environmentally friendly. Natural fiber also are 100% biodegradable that can completely dissolves into carbon, oxygen, hydrogen and further minerals.

1.3 Objective

- To design and fabricate the natural fiber polymer composites (NFPC) from kenaf fiber and polyester resin which is used in automotive application such as interior door panel.
- To quantify mechanical properties of NFPC such as tensile strength and flexural strength by doing several experiments and tests.
- To determine the effects of the presence of natural fiber in the composite and fiber orientation on mechanical properties of the composite.

1.4 The Scope of The Project

In this project, the kenaf fiber polymer composites (KFPC) is fabricate by combine the natural fiber which is kenaf fiber with the concentration of polyester resins and hardener. The manufacturing processes used to produce KFPC is hand layup and vacuum bagging process. Two KFPC samples will be produced that has different orientation of kenaf fiber which are random orientation and unidirectional (0°) orientation. One sample will be produced from concentration of polyester resin and hardener without kenaf fiber. The chemical treatment such alkaline and silane does not carry out in this project. The dimensions of the specimens for tensile strength and flexural strength will be followed the ASTM D3039 and ASTM D790 respectively. All samples will be undergoing several experiments and tests using Universal Testing Machine (UTM) to determine the properties such as tensile strength and flexural strength. Based on the testing results, the comparison for three samples can be done.

CHAPTER 2

LITERATURE REVIEW

2.1 Kenaf fiber polymer composites

Southeast and East Asian countries actively cultivate kenaf and it needs to go through separation process first to get the fiber that use in composites. For the fiber separation process for kenaf, the bast fibers can be separated from the core fibers using processes called decortating and retting [14]. Decortating is the process of employing a decorticator to separate the bast fiber from the core fiber. Retting can be done in three different ways, including mechanical, chemical, and water processes. Kenaf biocomposite was made from a mixture of matrix (resin) and natural fibers derived from the kenaf plant. Important parameters to consider in the production of a biocomposite are typically pressing pressure and pressing temperature (heat). As well as mechanical properties such as modulus of rupture (MOR), modulus of elasticity (MOE), and internal bonding (IB), Kenaf fiber polymer composites have physical properties such as swelling in thickness (TS) and water absorption (WA) [15]. As a result of low digestion pressure, fibers generated longer lengths, so panels made with these fibers showed higher TS with MOR and MOE than those made with other fibers. Mild refining conditions resulted in longer fiber with a higher aspect ratio, which gave the panels good bending strength but poor IB and physical properties. In contrast, severe refining conditions resulted in short fiber with a low aspect ratio, higher IB and physical properties, but lower bending strength.

2.2 Factors that effects natural fiber polymer composites properties

There are several factors that can influenced the properties of Natural Fiber Polymer Composites (NFPCs) [8]. Fiber orientation, fiber aspect ratio, shape factor, and fiber resin interfacial interaction are all elements that influence composite strength. The mechanical properties of NFRCs, on the other hand, are dependent not only on the chemical composition of the fiber, but also on physical and geometric parameters that have been discovered to have a significant impact on their mechanical properties [5]. Fiber length and volume fraction heavily influence the mechanical properties of Natural

Fiber reinforced composites, including tensile and flexural strength. The mechanical properties of natural fiber composites were heavily influenced by fiber orientation and the angle of orientation is seen to influence the damping properties of composites. Depending on the manufacturing process, the orientation of the fibers in the composites varies [8]. Due to varying fiber orientations, the composites' strength varies between samples. In addition, a hybrid composite combining two or more different types of fibers can enhance flexibility, strength, fatigue resistance, bending and membrane properties, fracture toughness, and impact resistance [9]. Designing hybrid composites requires careful consideration of suitable fibers and fiber characteristics. Chemical treatment like alkaline and silane also can improve the tensile properties of natural fiber by fixed the bonding problem with the polymer[10]. Moreover, the processing parameters such as temperature, time, and speed also influenced on tensile properties [11]. The tensile properties, flexural properties, and impact strength are affected by the different fiber size.

2.3 Design and manufacturing process of natural fiber polymer composites

For the natural fiber polymer composite (NFPC) manufacturing process, compression moulding is a more practicable approach than injection moulding because of its ease of operation and improved surface smoothness [8]. Composites made in the experimental setup of injection and compression moulding processes have higher tensile strengths compare to injection moulding process [8]. For the natural fiber composition in composite, the tensile modulus of 20 percent fiber composites was higher than virgin silicone because of the reinforcing effect of short fibres in composites. For example, the hardness of silicone fiber composites increased as the fiber composition increased from 5% to 10%, 15%, and 20%. The addition of fiber strengthened the composites, making them tougher and more rigid. For the mixing process temperature of natural fiber composite, the best mixing temperature is 190°C because the maximum strength at this temperature indicates stronger interfacial bonding [11]. For the chosen fiber size in manufacturing process, from the smallest fiber to the medium size, strength grew, then reduced after reaching the medium size. With fiber sizes between 125 and 300 μm, the maximum strength indicates stronger interfacial bonding and wettability [11]. The low strength of small fiber is most likely due to the increased surface area of smaller fiber, which leaves more surfaces nonreactive to the matrix. In addition, NFPC product can be fabricate using the design for sustainability (DFS) approach. The mold of NFPC product is fabricate using 3D printing method and a hand lay-up process [2].

2.4 Chemical treatment on the natural fiber

Chemical treatments to affect the surface properties of natural fibers for use in natural fiber-reinforced composites [12]. Alkali, silane, acetylation, benzoylation, acrylation, maleated coupling agents, isocyanates and permanganate are the chemical treatments that can be used on natural fiber. Kenaf fiber is frequently treated with alkaline, which is one of the most widely used chemical treatments on natural fibers when reinforcing thermoplastics and thermosets. As a result of treating fibers with an alkaline solution for a predetermined period of time, lignin, wax, and oils are removed from the fiber's external cell wall, cellulose is depolymerized, and short length crystallites are exposed [12], [13]. The alkaline treatment caused the globular pultrusions that were present in the untreated fibre to vanish, resulting in the creation of more voids. The mechanical bonding of fibre and matrix may be aided by these voids. In general, alkaline treatment reduced cement materials inside the fibre structure, which was followed by the removal of unstable components with rupture bonds. For alkaline treatment, the tensile strength of the treated natural fiber was much higher than that of the untreated fiber [10]. In addition, the concentration percentage of NaOH that used to treat the natural fiber have an effect on the treatment causing different mechanical properties in natural fuber. For example, natural fiber treated with 6% NaOH has the maximum tensile strength compared to natural fiber treated with 2%, 4%, and 8% NaOH.

2.5 Resins used in natural fiber polymer composites

Modified resins are now widely used in the fabrication of natural fiber-reinforced composites and the manufacture of various industrial products because of their better mechanical, thermal, and electrical qualities [18]. Melamine formaldehyde, urea formaldehyde, phenol formaldehyde, resorcinol formaldehyde, polyurethane, polyesters, and epoxies are the most common large-volume thermosetting resin systems but this article more focus on epoxy resin. In automotive and aerospace components and products, natural fiber-reinforced epoxy composites and nanocomposites provide better physical, mechanical, and thermal properties to produce high quality product. Moreover, thermoset resin molecules crosslink in this phase, resulting in exothermy, chemical shrinkage (Sh), and the formation of thermo-physical and thermo-mechanical properties [19]. Matrix shrinkage/expansion is a crucial element in determining the residual tension in a composite product as well as the form distortion that occurs during curing. These stresses cause a large number of defects in a composite part. Matrix shrinkage can be reduced by controlling and optimising the curing process to producing high-quality composite products. The linear component of apparent shrinkage in a thermoset resin casting system during cure was explored in a large number of studies now, including decoupling from T.E, Rheometer, and optical sensors.

2.6 Hybrid natural fiber polymer composites (HNFC)

The process of combining two or more fibres from different groups within a single matrix to manipulate the properties of fiber-reinforced composite materials is known as hybridization [16]. Natural–natural fibre, natural–synthetic fibres, natural fibre with carbonaceous materials, and natural fibre with metal can all be used to hybridise natural fiber-reinforced polymer composites. The behaviour of hybrid composites seems to be just the weighted sum of the constituent parts, which is affected by factors including the fiber matrix interface, fiber length, chemical composition of the reinforcement, and hybrid design. Van der Waals forces, hydrogen bonds, and weak electrostatic interactions can cause the HNFC interactions to be weak or strong depending on how the components interact chemically. The resulting composite which is hybrid composites is a unique product with improved mechanical and thermal properties than single fibre-reinforced polymer composites [17]. In addition, the factors that influenced the mechanical properties of hybrid composites are influenced by the treatment and modification of fiber, fiber orientation, and fiber physical properties. Lastly, Hybrid biocomposites made comprised of a bio fibre and a nano-reinforced bio-based polymer can be used to prevent environmental difficulties while maintaining desired industrial qualities. Fig. 2.1 shows examples of the hybridization of a woven kenaf with carbon fibers mat-reinforced epoxy composite.

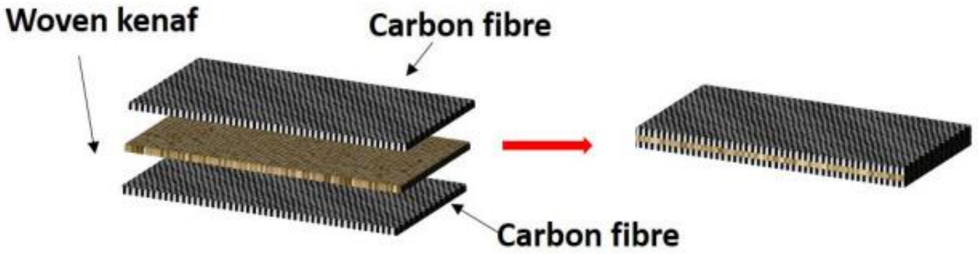


Figure 2.1 Schematic diagram of hybridization of a woven kenaf with carbon fibre [16]

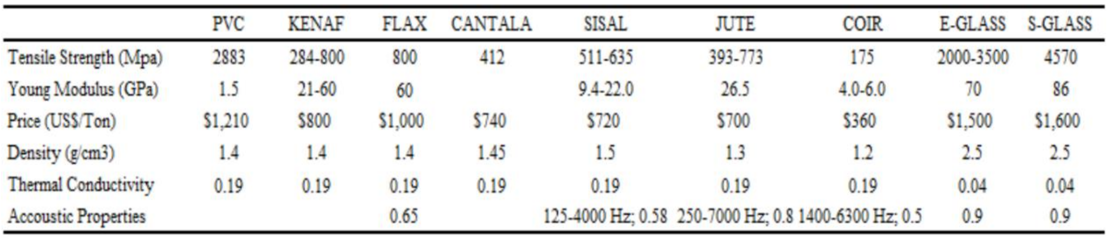
2.7 Application of natural fiber reinforced in automotive industry.

The automotive industry sector contributes to global pollution because it uses materials that cannot be recycled and emits harmful substances from its fuel emissions, creating an environmental issue [20]. However, the automotive interior industry has shifted in recent years and increasingly utilized natural fiber based bio-composite, as opposed to conventional materials like fiberglass, carbon, silicon carbide, and acrylic oxide. The potential and competitiveness of natural fiber based bio-composite as a possible car interior material can be analyse using methods such as market trend, material comparison, value chain analysis, and economic analysis.

Based on the market trend, Europe has the largest market share because car manufacturers that use natural fibre-based bio-composite are mostly from Europe, but the market share in Asia is expected to increase from 3% to 9% in 2016, while the market share in other territories is decreasing. However, Europe still has the largest market share (59%) from total sales of more than € 4.5 billion, so it can be stated that Europe has the highest demand for natural fibre compared to other territories, and it can be concluded that natural fibre suppliers have a good prospect in the European automotive market. According to a 1999 study, each of the 53 million vehicles produced globally each year uses up to 20 kg of natural fibre. It also means that 1000 – 3000 tonnes of natural fibre are used each year to produce a new model of car. Based on the data presented above, we can estimate that the global demand for natural fibre is around 1.06 billion kg per year. When the demand for natural fibres continues to rise year after year, it is viewed as an appealing field for investment in natural fibre plantation and production to meet the demand.

The main characteristics of car interior materials are durability, weight, and price. Material comparison method will analyse the characteristics of each material used for car interiors as shown in Table 2.1. In order for the temperature inside the car not to keep rising, the material of the car interior must have a low thermal conductivity. Based on table 1, All of the comparative materials have a thermal conductivity of 0.19 W/ (m.K), except for fiberglass which only has 0.04 W/ (m.K) and can be concluded that it is a better heat insulator than other materials. The material with the longest range of sound absorption is jute fiber, but Fiberglass still has a higher noise reduction coefficient (NRC). Even with lower tensile strength than fiberglass, natural fiber has a better price, lower energy consumption, lighter weight, and is recyclable for sustainable manufacturing, as shown in Figure 2.1. As part of the chosen strategic plan for the company, value chain analysis evaluates all the activities that add value in order to gain an advantage. For example, Figure 2.2 shows the value chain of natural fiber based bio-composite for car interiors. Lastly, economic analysis will compare the natural fiber with synthetic fiber to determine whether natural fiber worth it to use or not in interior automotive application.

Table 2.1:Material characteristics and properties comparison



	PVC	KENAF	FLAX	CANTALA	SISAL	JUTE	COIR	E-GLASS	S-GLASS
Tensile Strength (Mpa)	2883	284-800	800	412	511-635	393-773	175	2000-3500	4570
Young Modulus (GPa)	1.5	21-60	60		9.4-22.0	26.5	4.0-6.0	70	86
Price (US$/Ton)	$1,210	$800	$1,000	$740	$720	$700	$360	$1,500	$1,600
Density (g/cm3)	1.4	1.4	1.4	1.45	1.5	1.3	1.2	2.5	2.5
Thermal Conductivity	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.04	0.04
Accoustic Properties			0.65		125-4000 Hz; 0.58	250-7000 Hz; 0.8	1400-6300 Hz; 0.5	0.9	0.9

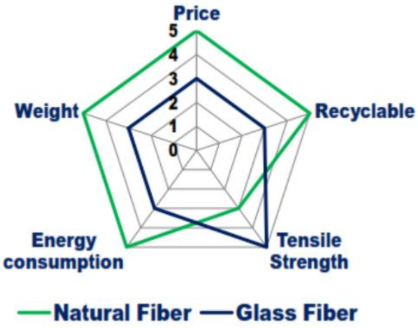


Figure 2.2: Natural fiber and fiberglass reinforced composite trade off [20]

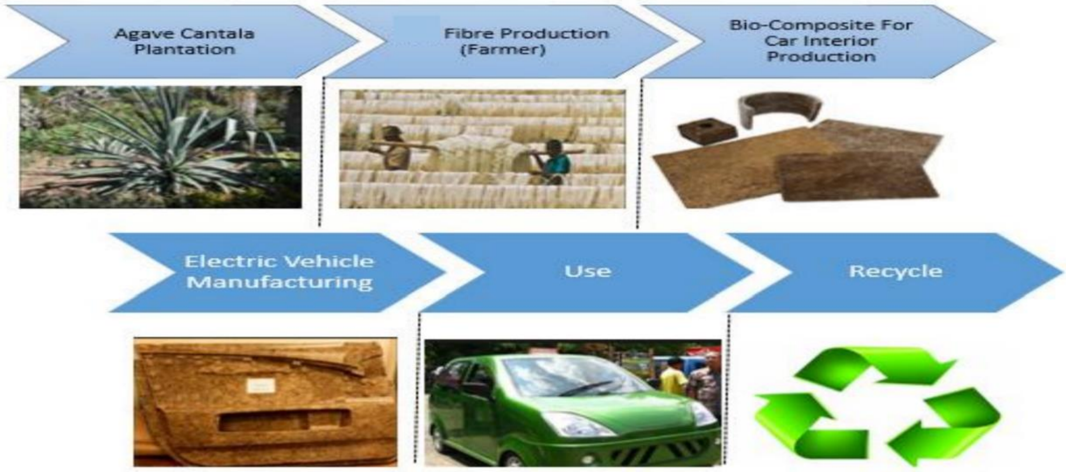


Figure 2.3: Value chain of natural fiber composite for automotive interior production [20]

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Raw material preparation

The kenaf fiber was obtained from the Lembaga Kenaf dan Tembakau Negara (LKTN) as main material for this project and act as reinforcing fibres for the composites. The grade of kenaf fiber was chosen from the list given by the LKTN and the grade of kenaf fiber that has been selected is Grade B bio retting fiber (SKM2-Bio Grade B). The basic properties of the selected grade B kenaf fiber was shown in the table 3.1.

Figure 3.1: Grade B kenaf fiber

Table 3.1: Basic properties of grade B kenaf fiber [34]

Colour	Light brown (>80%)
Colour rating	Fairly good
Lustre	Good
Brightness (L)	61 to 70
Humidity	<12%
Mixing of impurities	<2%
Unretted fiber	<5%

Length	700 mm – 1200 mm
Major defect	Permitted up to 10% of total major defect
Type of defect	Center root, entangled croppy end fiber, gummy fibre and over ratted fibre/dazed fibre

A polymer matrix or resin that used in this project is polyester resin and its hardener. Polyester resin and hardener were got from CL Composites SDN BHD. The type of polyester resin was got from this company is Resin Reversol P-9801W DURA+ is a rigid, low reactivity, waxed, thixotropic, economy general purpose orthophthalic unsaturated polyester resin. Methyl Ethyl Ketone Peroxide (MEKP) is used as a catalyst/hardener and is pre-promoted for ambient temperature curing. The environment's temperature and the type of catalyst being used can affect how long it takes to cure and demould. In general, use more catalyst in cold or rainy conditions and less in hot ones. Polyester resin has the advantages of being appropriate for spray-up and hand lay-up applications, slower glass fibre wetting, and simple air release during rollout. General fiberglass-reinforced manufactured components, maritime applications, and other applications for structural fibre reinforcement are typical uses for polyester resin. The specifications and typical properties of selected polyester resin were shown in table 3.2 and table 3.3 respectively.

Table 3.2: Specifications of polyester resin [35]

Appearance	Pink
Non-Volatile, %	57.5 ± 2.5
Viscosity at 25 °C, cps	500 – 600
Thixotropic Index	2.0 – 3.0
Gel time at 25 °C, minutes	25 – 30

Table 3.3: Typical properties of polyester [35]

Property	Value	Test Method
Tensile Strength, MPa	52	BS2782-320C
Tensile Modulus, MPa	3358	BS2782-320C
Elongation at Break, %	1.6	BS2782-320C
Water Absorption 24hr at 25 °C, mg	18	BS2782-430C
Deflection Temperature (1.80MPa Load), °C	59	BS2782-121A
Barcol Hardness (Model GYZJ 934-1)	42	BS2782-1001

3.2 Kenaf fiber orientation

Kenaf fibers were arranged two orientation which are random and unidirectional (0°) as shown in Figure 3.3 before applied the mixture of polyester resin and hardener using hand layup and vacuum bagging process. The objective to has two different orientation is to determine the effects of different orientation on kenaf fiber polymer composite (KFPC) mechanical properties such as tensile and flexural strength. In addition, one specimen was produced by using the mixture of polyester resin and hardener only without kenaf fiber. The comparison can be done between specimen of kenaf fiber polymer composite and specimen of mixture of polyester resin and hardener to determine the effect of natural fiber in composite as reinforced fiber.

Figure 3.2: Random orientation (left) and unidirectional orientation (right)

Table 3.4: Project variables

Specimen	Type of natural fiber	Type of resin	Fiber orientation	Manufacturing process
1	Kenaf fiber	Polyester resin	Random	Vacuum bagging
2	Kenaf fiber	Polyester resin	Unidirectional	Vacuum bagging
3	-	Polyester resin	-	Resin casting

3.3 Kenaf fiber polymer composite fabrication

The kenaf fiber that obtained from LKTN was cut into the length of 20 cm to 35 cm. The cut kenaf fiber were arranged in two orientation which are random and unidirectional. For the random orientation, the adhesive spray was used during arrangement process for effectively stick kenaf fibers make it easily to arranged the kenaf fiber. For unidirectional orientation, the kenaf fibers were arranged in straight line and at the end of the arrangement the kenaf fiber is sewn so that the kenaf fiber does not loose during fabricated process. The two of arranged kenaf fiber were dried in hot air oven at a temperature of 60 °C for 24 hours. The weight for both arranged kenaf fiber were taken and both have the weight around 62.5 g. After all the materials and apparatus for vacuum bagging were prepared, the 250 g of polyester resin was mixed with the 5 g of Methyl Ethyl Ketone Peroxide (hardener) by using the mixing ratio of 2%. The weight of polyester resin needed to be 4 times the weight of natural fiber. The mixture of polyester and hardener was applied on the kenaf fiber using hand layup techniques at room temperature. Rollers are used to spread resin to kenaf fibers that are in the form of random and unidirectional mat. In order to create a stronger interaction between the reinforcement and the matrix material, the roller is used to force into the resin into the kenaf fiber.

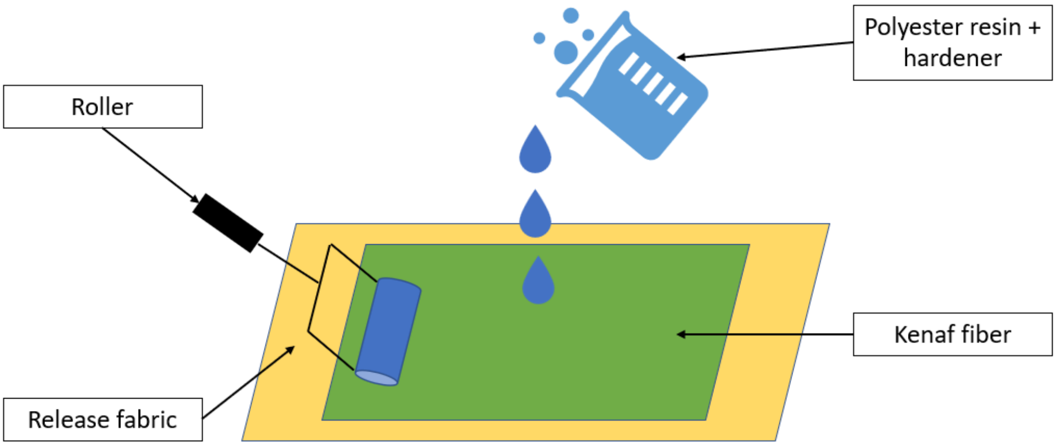


Figure 3.3: Hand layup process

After that, the hand layup kenaf fiber was undergoing vacuum bagging process. After hand layup process, A layer of sealant tape was lay down around the perimeter of the part, leaving some space between it and the laminated kenaf fiber. The area where the tape is put down was cleaned from polyester residue and stray fibers. Then, release fabric was laid directly on top of the wet laminated kenaf fiber. The fabric is released with a textured finish, which reduces the amount of surface preparation needed before secondary bonding. The 300 mm x 300 mm steel plate was put on the release fabric as a weight and the produced kenaf fiber polymer composite (KFPC) will take the shape of the plate. The breather fabric was laid directly on top of the plate. The breather fabric will absorb the vacuum pressure consolidates the KFPC when it squeezed-out the KFPC. Vacuum bag was used to enclose and seal the KFPC from the environment. The vacuum bag was cut oversized and carefully stick with the sealant tape in step 10. Vacuum pump was turned on to applied the vacuum pressure. After 15 minutes, the vacuum pump was turned off when making sure no air escapes and the vacuum bag did not loose. The KFPC in the vacuum bag was left to cure for 1 day at room temperature. The finished specimens were cut using saw followed the dimensions give in the ASTM standard for tensile and flexural testing.

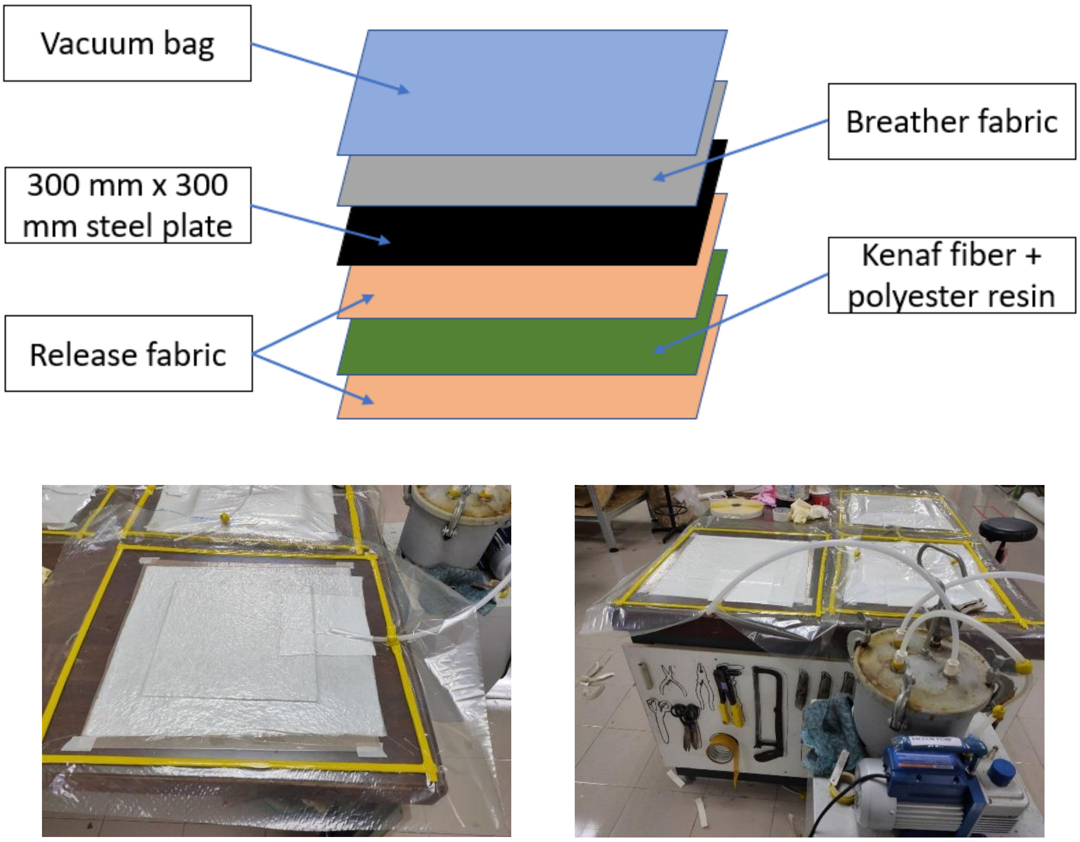


Figure 3.4: Vacuum bagging process

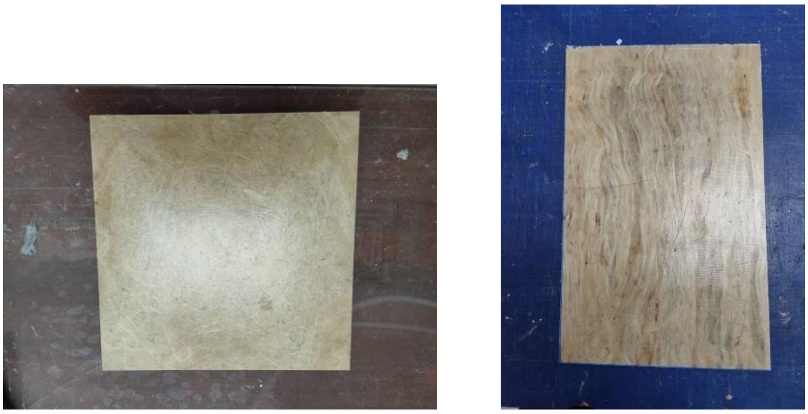


Figure 3.5: Finished KFPC plates for random (left) and unidirectional (right) orientation.

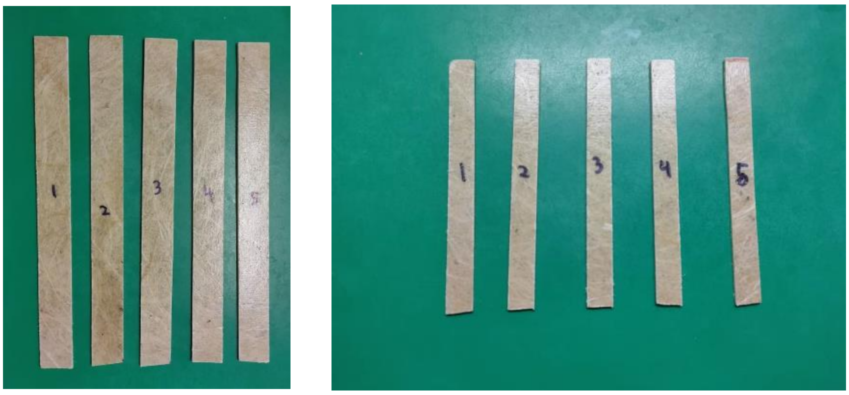


Figure 3.6: Cut samples of random KFPC followed ASTM standard for tensile (left) and flexural (right) tests.

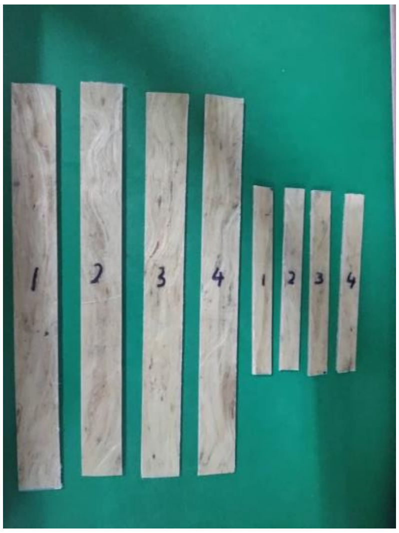


Figure 3.7: Cut samples of unidirectional (0°) KFPC followed ASTM standard for tensile (left) and flexural (right) tests.

In addition, the samples of polyester and hardener also was produced by using resin casting process. The moulds that has shape and dimensions of the specimens that followed ASTM standard for the tensile and flexural tests were took from the Composite Lab at School of Aerospace Engineering. The mixture of 100g polyester and 2 g hardener were brewed by using the mixing ratio of 2%. The mixture of polyester and hardener was carefully poured to fill the mould cavity until its full. The poured mixtures were left to cure for 1 day at room temperature.

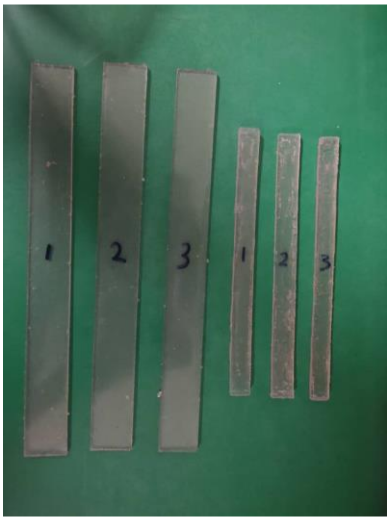


Figure 3.8: Polyester resin and hardener samples followed ASTM standard for tensile (left) and flexural (right) tests.

3.4 Testing methods

There are two testing methods were used in my final year project to tested my specimens which are tensile test and flexural test. For the tensile test, tensile strength of the specimens was tested until its break. For the flexural test or also call 3-point bending test, the the flexural strength of the specimen was tested by bended the specimen until its reach 5.0% of deflection or until its fracture. The methods that used for the tensile and flexural tests were shown in the Table 3.5.

Table 3.5: Description of test method

Test	**Method**	**Equipment**
Tensile properties	ASTM D3039 (Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials)	Universal Testing Machine (UTM)
Flexural strength	ASTM D790 (Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials)	

3.4.1 Tensile properties testing method (ASTM D3039)

In this test method, the in-plane tensile properties of polymer matrix composite materials reinforced with kenaf fibers are determined. The tensile test specimens were made in accordance with ASTM D3039 standards. At a constant stroke rate of 2 mm/min, the specimen was loaded in tension.

The first operation is specimen insertion, which involves aligning the gripped specimen's long axis with the test direction before inserting the specimen into the testing machine's grips. Tightening the grips while monitoring the pressure applied on pressure controlled (hydraulic or pneumatic) grips is recommended. Then, transducer installation that attach the strain-indicating transducer(s) symmetrically along the mid-span and mid-width of the specimen if strain response is to be determined. The strain-recording instrumentation should be attached to the specimen's transducers. After that, the load was applied on the specimen at the specified rate until failure and the data was recorded. Load versus strain (or transducer displacement) was recorded continuously or at frequent regular intervals for data collection. If a transition zone or first ply failures are seen, the load, strain, and manner of damage at such places are recorded. The maximum load, the failure load, and the strain (or transducer displacement) was recorded at the moment of rupture if the specimen is to be failed. The mode and location of failure of the specimen were recorded for failure mode, and a standard description utilising the three-part failure mode code was chosen. Finally, for grip or tab failures, re-examine the mechanisms of load introduction into the material if a large number of failures in a sample population occur within one specimen width of the tab or grip. Several factors should be taken into consideration, including tab alignment, tab material, tab angle, tab adhesive, grip type, grip pressure, and grip alignment.

Specimen geometries:

Table 3.6: Tensile testing specimen geometries

Thickness	2.5 mm
Overall length	250 mm
Span length	150 mm
width	25
Tab type	Emery cloth
Specimen shape	Rectangular bar

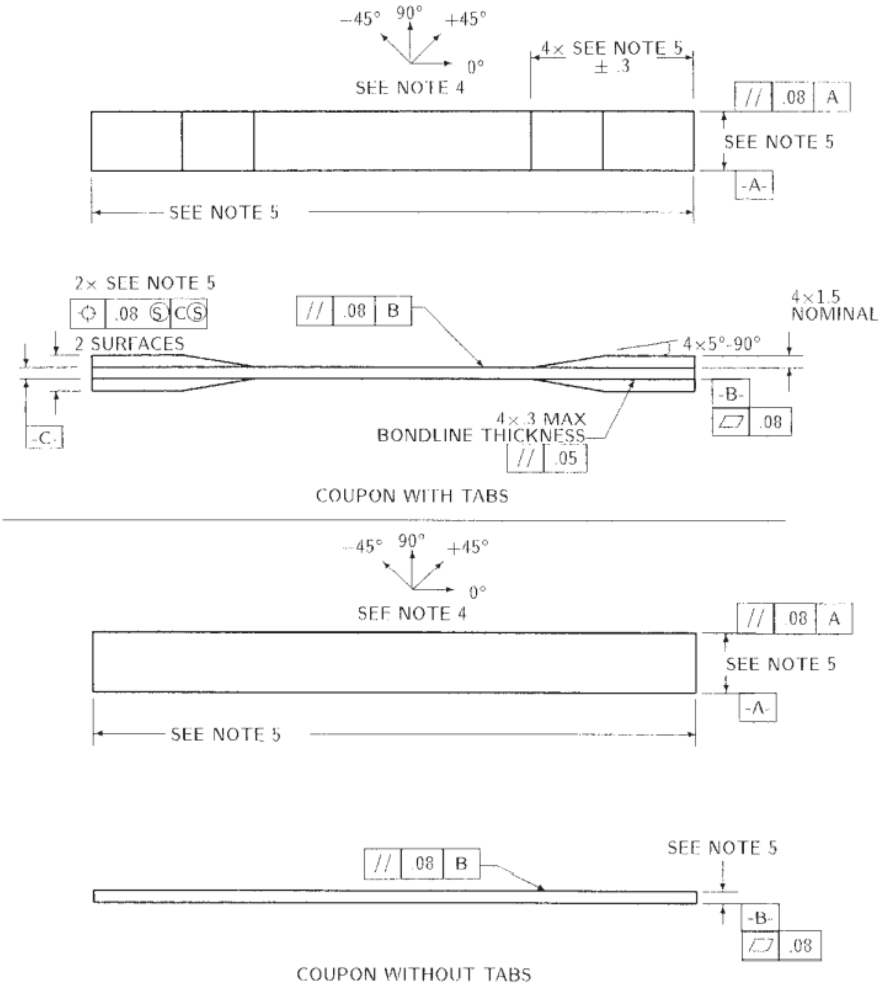
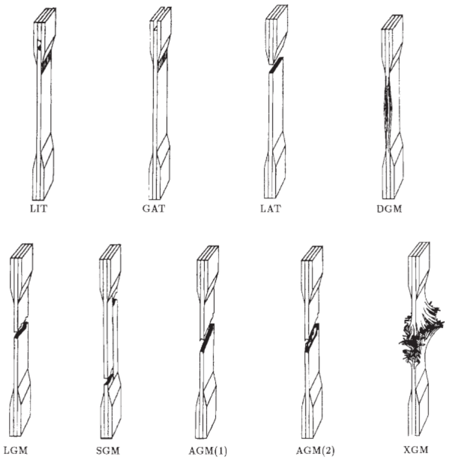


Figure 3.9: Tensile testing specimen drawing in SI



First Character

Failure Type	Code
Angled	A
edge Delamination	D
Grip/tab	G
Lateral	L
Multi-mode	M(xyz)
long. Splitting	S
eXplosive	X
Other	O

Second Character

Failure Area	Code
Inside grip/tab	I
At grip/tab	A
<1W from grip/tab	W
Gage	G
Multiple areas	M
Various	V
Unknown	U

Third Character

Failure Location	Code
Bottom	B
Top	T
Left	L
Right	R
Middle	M
Various	V
Unknown	U

Figure 3.10: Three-part failure mode code

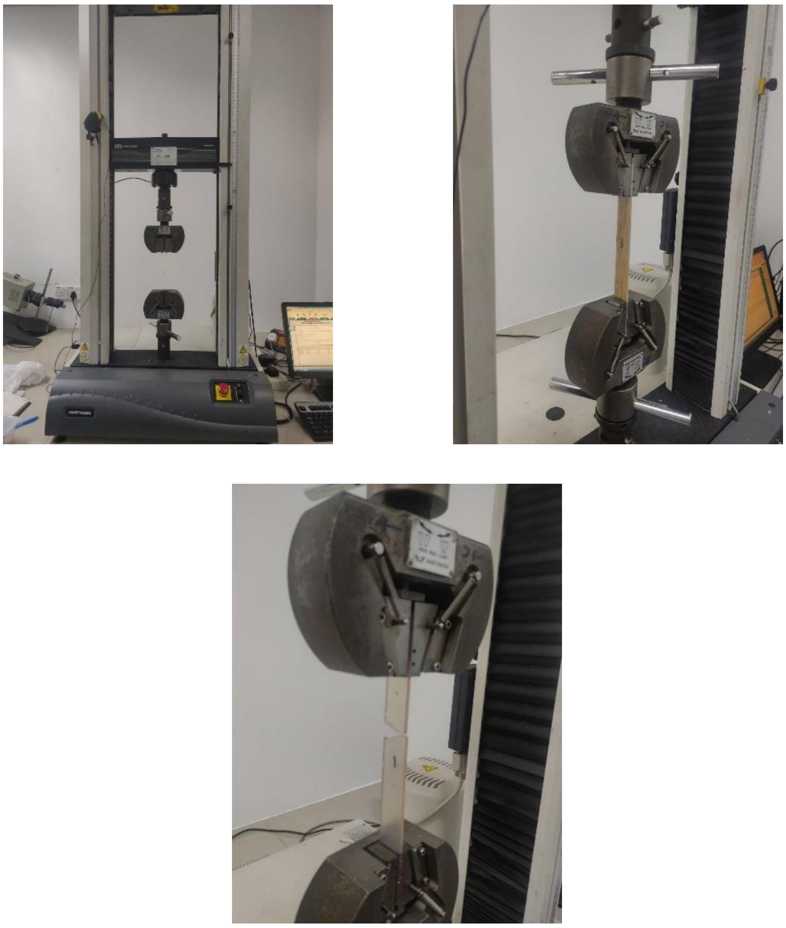


Figure 3.11: Tensile testing using universal testing machine (UTM)

3.4.2 Flexural strength testing method (ASTM D790):

The test methods described here are designed to determine the flexural properties of kenaf fiber polymer composites (KFPC) as rectangular bars molded directly or cut from sheets, plates, or molded shapes. Flexural strength was determined using 3-point bending method in ASTM D790 using universal testing machine (UTM). The support span length of the sample is 60 mm and the strain rate were 2mm/min.

A rectangular-sectioned bar (KFPC samples) is supported by two supports and loaded through a loading nose located midway between the supports. Except in the case of certain laminated materials, a support span-to-depth ratio of 16:1 was used. The loading nose and supports was aligned so that their axes are parallel and the loading nose is midway between the supports. The apparatus's parallelism was checked using a plate with parallel grooves into which the loading nose and supports will fit when properly aligned. The specimen was placed on the supports with its long axis perpendicular to the loading nose and supports. The load was applied to the specimen at the specified crosshead rate and the load-deflection data simultaneously recorded.

Next, deflection was measured using either a gauge under the specimen in contact with it at the centre of the support span, with the gauge mounted stationary relative to the specimen supports, or by measuring the motion of the loading nose relative to the supports. Load-deflection curves was used to calculate flexural strength, chord or secant modulus, or tangent modulus of elasticity, as well as total work as measured by the area under the load-deflection curve. Toe compensation is required to correct for specimen seating and indentation, as well as machine deflections. The test was terminated when the maximum strain in the outer surface of the test specimen has reached 0.05 mm/mm [in./in.] or at break if break occurs prior to reaching the maximum strain.

Specimen geometries:

Table 3.7: Flexural testing specimen geometries

Thickness	Less than 3.2 mm
Overall length	125 mm
Span length	60 mm
Width	12.7 mm
Specimen shape	Rectangular bar

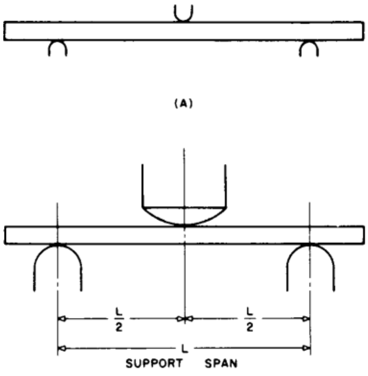


Figure 3.12: Flexural testing specimen drawing

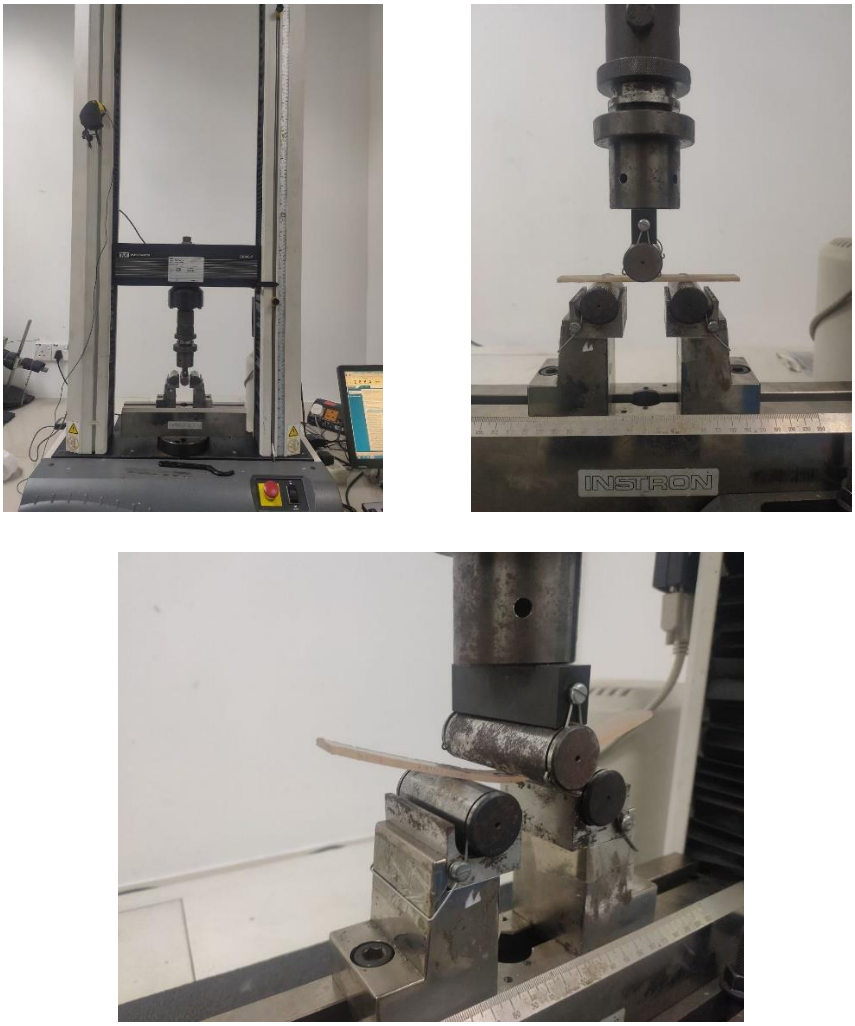


Figure 3.13: Flexural testing using universal testing machine (UTM)