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FABRICATION AND EXPERIMENTAL INVESTIGATION ON THE MECHANICAL & SURFACE CHARACTERIZATION OF HYBRID COMPOSITES INTEGRATED WITH EPOXY

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Abstract
Composite materials play a vital role in wide range applications. Their adaptability to different situations & desirable attracted many industries. In the automobile industry, the demand for the light weight components is increasing day by day. In this project, two different fibers namely glass and palm fibers to prepare the composite in the form of straight rectangular plates. We fabricated the composite based on the aerospace application. The hybrid composite was made using two fibers synthetic fiber and natural fiber. The synthetic fiber is glass fiber and natural fiber is palm fiber. And to prepare a hybrid composite plate the epoxy used is LY556 and HY951 in the ratio 1:10.Hand lay-up technique is used to fabricate the composite plate using rule of mixture method. To prepare a composite plate here we consider 5 layers with the orientation of 0/30 and 0/45.The fibers are taken in the form of UD-MAT. The weight of glass fiber to the epoxy is taken in the ratio of 1:1.2 and for the palm fiber epoxy is taken as 1:4.Here the fiber and epoxy weights are taken using mini weighing machine. The quantity of epoxy is taken based on fiber weight calculations. The fabricated composite plate is then cut into ASTM D638 standards. The specimens are then tested for the mechanical characterization such as compressive strength. Advanced surface testing on the composites such as hardness, surface roughness were performed. The surface roughness is found for both top and bottom layers of the composite plate. The results for the surface roughness indicate that the Rz value found is 3X times the Ra value. The surface hardness indicate that 0/30 orientation for the glass had the highest value compared with the 0/45.Whereas 0/45 orientation for the palm fiber records the highest value compared to the 0/30.

Introduction
Two or more chemically different constituents combined macroscopically to yield a useful material. Composite materials have played an important role throughout human history, from housing early civilizations to enabling future innovations. Composites offer many benefits; the key among them are corrosion resistance, design flexibility, durability, light weight, and strength.
Composites have permeated our everyday lives such as products that are

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used in constructions, medical applications, oil and gas, transportation, sports, aerospace, and many more. Some applications, such as rocket ships, probably would not get off the ground without composite materials.
This chapter addresses the advantages of fiber composite materials as well as fundamental effects, product development, and applications of fiber composites, including material chemistry, designing, manufacturing, properties, and utilization of the materials in various applications. The development and need for composite materials also result in the fiber-reinforced polymers (frp) industry.
By 1945, more than 7 million pounds of glass fibers were used for various products, primarily for military applications. Composite materials continued to take off after the war and grew rapidly through the 1950s. The composite innovators were ambitiously trying to introduce composites into other markets such as aerospace, construction, and transportation.
Soon the benefits of frp composites, especially its corrosion resistance, became known to the public sector. Boats were one obvious product that benefited. The first composite commercial boat hull was introduced in 1946. A full automobile body was made from composite and tested in 1947. This led to the development of the 1953 chevrolet corvette. Nowadays, the composite industry is still evolving, with much of the growth now focused around renewable energy.

The engineers can also select properties such as resistance to heat, chemicals, and weathering by choosing an appropriate matrix material. In recent years, an increasing environmental consciousness and awareness of the need for sustainable development have raised interest in using natural fibers as reinforcements in composites to replace synthetic fibers. This chapter seeks to provide an overview of the science and technology in relation to the composite material, manufacturing process, and utilization.

1.2 Reinforcements

Composite reinforcements can be in various forms such as fibers, flakes, or particles. Each of these has its own properties which can be contributed to the composites, and therefore, each has its own area of applications. Among the forms, fibers are the most commonly used in composite applications, and they have the most influence on the properties of the composite materials.
These reasons are that the fibers have the high aspect ratio between length and diameter, which can provide effective shear stress transfer between the matrix and the fibers, and the ability to process and manufacture the composites part in various shapes using different techniques. Some of the common reinforcing fibers include:

- Carbon or graphite (C)-high stiffness, strength, and cost-unidirectional
- Glass (Si02)-amorphous, isotropic, low cost-often used with polymers
- Organic fibers-high stiffness, strength, low cost
- Silicon carbide fibers (Sic)-high temperature stability-used with metals and ceramics
- Boron fibers (B)-used to reinforce metals
- Metallic fibers (Mg, Ti)-used with metal matrices

1.3 Composite manufacturing techniques

There are several methods for fabricating composite materials. The selection of a method for a part will depend on the materials, the part design, the performance, and the end-use or application.

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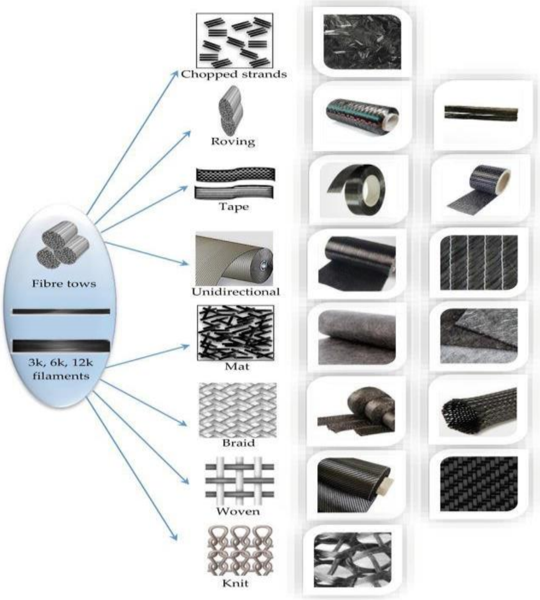

Figure 1.1 Types of weaving of composites

1.4 Composite properties

The polymer composite materials are lightweight, which increases the fuel efficiency of vehicles manufactured from composites and gives them structural stability. In addition, they offer a high strength-to-weight ratio and increased heat resistance.

Composites have very different properties and applications depending on the type of matrix, reinforcement, ratio between them, formulations, processing etc. The bonding strength between fiber and polymer matrix in the composite is considered one of the major factors in order to obtain superior fiber reinforcement polymer composite properties. The growth of the composites market can be attributed to increased uses in the aerospace, defense, and transportation applications. The global composite materials market is expected to reach an estimated $40.2 billion by 2024, and it is forecasted to grow at a cagr of 3.3% from 2019 to 2024. The global composite product market is expected to reach an estimated $114.7 billion by 2024.

1.5 Composite applications

The most widely used form of fiber-reinforced polymer is a laminar structure, made by stacking and bonding thin layers of fiber and polymer until the desired thickness is obtained. By changing the fiber orientation among layers in the laminate structures, a specified level of anisotropy in composite properties can be achieved. Composites offer many benefits such as corrosion resistance, light weight, strength, lower material costs, improved productivity, design flexibility, and durability. Therefore, the wide range of industries uses composite materials and some of their common applications. There some applications where the composites are used.

- Aerospace
- Appliance/business
- Architecture
- Automotive and transportation
- Construction and infrastructure
- Corrosive environments
- Electrical
- Energy
- Marine
- Sports and recreation

Aerospace

The major original equipment manufacturers (oems) such as airbus and boeing have shown the potential of using composite materials for large-scale applications in aviation. NASA is continually looking to composite manufacturers for innovative approaches and space solutions for rockets and other space crafts. Composites with thermoset are being specified for bulkheads, fuselages, wings, and other applications

in commercial, civilian, and military aerospace applications. There are several other applications of composites in the areas such as air-foil surfaces, antenna structures, compressor blades, engine bay doors, fan blades, flywheels, helicopter transmission structures, jet

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engines, radar, rocket engines, solar reflectors, satellite structures, turbine blades, turbine shafts, rotor shafts in helicopters, wing box structures, etc.

Appliance/business

Composite materials offer flexibility in design and processing; therefore composite materials can be used as alternatives for metal alloys in appliances. Unlike most other industries, trends within the appliance segment move quite quickly. In addition, design and function are subject to both technology advancements and changing consumer taste. Composite materials are being used in appliance and business equipment such as equipment panels, frames, handles and trims in appliances, power tools, and many other applications. Composites are being utilized for the appliance industry in dishwashers, dryers, freezers, ovens, ranges, refrigerators, and washers. The components in the equipment that were utilized composites include consoles, control panels, handles, kick plates, knobs, motor housings, shelf brackets, side trims, vent trims, and many others.

Architecture

With their aesthetic qualities, functionality, and versatility, the composite materials are becoming the material of choice for architectural applications. Composite materials allow architects to create designs that are impractical or impossible with traditional materials, improve thermal performance and energy efficiency of building materials, and meet building code requirements. Composite materials also offer design flexibility and can be molded into complex shapes. They can be corrugated, curved, ribbed, or contoured in a variety of ways with varying thickness. Further, a traditional look such as copper, chrome or gold, marble, and stone can be achieved at a fraction of the cost using composite materials. Therefore, the architecture community is experiencing substantial growth in the understanding and use of composites in commercial and residential buildings.

Automotive and transportation

The automotive industry is no stranger to composites. This is one of the largest markets for composite materials. Weight reduction is the greatest advantage of composite material usage. A lower-weight vehicle or truck is more fuel-efficient because it requires less fuel to propel itself forward. In addition to enabling ground

breaking vehicle designs, composites help make vehicles lighter and more fuel efficient. The composite materials are used in bearing materials, bodies, connecting rod, crankshafts, cylinder, engines, piston, etc. While fibre-reinforced polymers such as cfrp in cars get most of the attention, composites also play a big role in increasing fuel efficiency in trucks and transport systems.

Construction and infrastructure

Construction is one of the largest markets for composites globally. The composites can be made to have a very high strength and ideal construction materials. Thermoset composites are replacing many traditional materials for home and offices' architectural components including doors, fixtures, molding, roofing, shower stalls, swimming pools, vanity sinks, wall panels, and window frames. Composites are used all over the world to help construct and repair a wide variety of infrastructure applications, from buildings and bridges to roads, railways, and pilings.

Corrosive environments

Products made from composite materials provide long-term resistance to severe chemical conditions and temperature environments. Composites are often the material of choice for applications in chemical handling applications, corrosive environments, outdoor exposure, and other severe environments such as chemical processing plants, oil and gas refineries, pulp and paper converting, and water treatment facilities. Common applications include

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cabinets, ducts, fans, grating, hoods, pumps, and tanks. Fibre-reinforced polymer composite pipes are used for everything from sewer upgrades and wastewater projects to desalination, oil, and gas applications. When corrosion becomes a problem with pipes made with traditional materials, fiber-reinforced polymer is a solution.

Electrical

With the rapid growth of the electronics industry, and with strong dielectric properties including arc and track resistance, the composite materials are finding more and more in electronic applications. With strong dielectric properties including arc and track resistance, thermoset components include. Applications and components include arc chutes, arc shields, bus supports and lighting components, circuit breakers, control system components, metering devices, microwave antennas, motor controls, standoff insulators, standoffs and pole line hardware and printed wiring boards, substation equipment, switchgear, terminal blocks, and terminal boards.

Energy

Material technology has grown from the early days of glass fibers as major reinforcements for composite material to carbon fibers which are lighter and stronger. The advancements in composites, particularly those from the US department of energy, are redefining the energy industry. Composites help enable the use of wind and solar power and improve the efficiency of traditional energy suppliers. Composite materials offer wind manufacturers strength and flexibility in processing with the added benefit of a lightweight components and products. The wind industry has set installation records over the last couple years. According to the global wind energy council, the trend for this industry may continue with global wind capacity predicted to double in the next few years. Composites play a vital role in the manufacture of structures such as wind turbine blades.

Marine

Just like in the other engineering areas, the main struggle of naval architecture is to achieve a structure as light as possible. The marine industry uses composites to help make hulls lighter and more damage-resistant. With their corrosion resistance and light-weighting attributes, marine composite applications include boat hulls, bulkheads, deck, mast, propeller, and other components for military, commercial, and recreational boats and ships. Composites can be found in many more areas of a maritime vessel, including interior moldings and furniture on super yachts.

Sports and recreation

The fibre-reinforced composite materials possess some excellent characteristics, including easy moulding, high elastic modulus, high strength, light in weight, good corrosion resistance, and so on. Therefore, fibre-reinforced composite materials have extensive applications in production the manufacturing of sports equipment.

From bicycle frames, bobsleds fishing poles, football helmets, hockey sticks, horizontal bars, jumping board, kayaks, parallel bars, props, tennis rackets, to rowing, carbon fibres, and fibreglass composite materials help athletes reach their highest performance capabilities and provide durable and lightweight equipment.

1.6 Summary

Composites have many advantages; a wide range of material combinations can be used in composites, which allows for design flexibility. The composites also can be easily moulded into complicated shapes. The materials can be custom tailored to fit unique specifications. Composites are light in weight compared to most woods and

metals and lower density as compared to many metals. They are stronger than some other materials. The materials resist damage from weather and harsh

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chemicals. Composites have a long service life and require little maintenance.

Due to the wide variety of available reinforcement, matrix, and their forms, manufacturing processes, and each resulting in their own characteristic composite products, the design possibilities for composite products are numerous. Therefore, a composite and its manufacturing process can be chosen to best fit the developing rural societies in which the products will be made and applied. Composite materials' research continues. The areas of interest are nanomaterials—materials with extremely small molecular structures and bio-based polymers. To facilitate the advantages of the composites, several aspects must be considered: (a) concept development, (b) material selection and formulation, (c) material design, (d) product manufacturing,
(e) market, and (f) regulations.

1.7 Composite Matrix Materials

A fiber-reinforced composite (FRC) is a high-performance composite material made up of three components - the fibers as the discontinuous or dispersed phase, the matrix acts as the continuous phase, and the fine interphase region or the interface.

The matrix is basically a homogeneous and monolithic material in which a fiber system of a composite is embedded. It is completely continuous. The matrix provides a medium for binding and holding reinforcements together into a solid. It offers protection to the reinforcements from environmental damage, serves to transfer load, and provides finish, texture, color, durability and functionality.

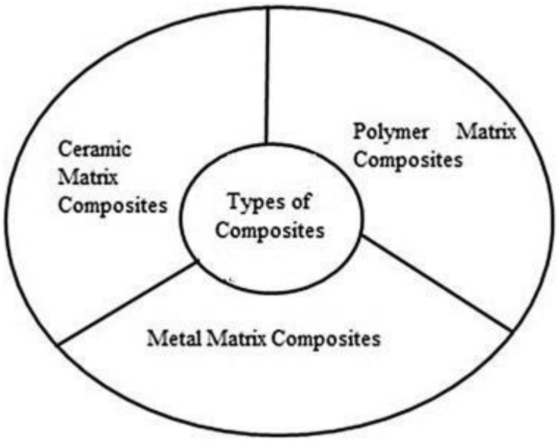

Figure 1.2 Types of Composite Matrix Materials

Ceramic matrix - Ceramic matrix composites (CMCs) are a subgroup of composite materials. They consist of ceramic fibers embedded in a ceramic matrix, thus forming a ceramic fiber reinforced ceramic (CFRC) material. The matrix and fibers can consist of any ceramic material. CMC materials were designed to overcome the major disadvantages such as low fracture toughness, brittleness, and limited thermal shock resistance, faced by the traditional technical ceramics.

Metal matrix - Metal matrix composites (MMCs) are composite materials that contain at least two constituent parts – a metal and another material or a different metal. The metal matrix is reinforced with the other material to improve strength and wear. Where three or more constituent parts are present, it is called a hybrid composite. In structural applications, the matrix is usually composed of a lighter metal such as magnesium, titanium, or aluminum. In high temperature applications, cobalt and cobalt-nickel alloy matrices are common. Typical MMC's manufacturing is basically divided into three types: solid, liquid, and vapor.

Continuous carbon, silicon carbide, or ceramic fibers are some of the materials that can be embedded in a metallic matrix material. MMCs are fire resistant, operate in a wide range of temperatures,

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do not absorb moisture, and possess better electrical and thermal conductivity. They have also found applications to be resistant to radiation damage, and to not suffer from outgassing. Most metals and alloys make good matrices for composite applications.

Polymer matrix - Polymer matrix composites (PMCs) can be divided into three sub- types, namely, thermoset, thermoplastic, and rubber. Polymer is a large molecule composed of repeating structural units connected by covalent chemical bonds. PMC's consist of a polymer matrix combined with a fibrous reinforcing dispersed phase. They are cheaper with easier fabrication methods. PMC's are less dense than metals or ceramics, can resist atmospheric and other forms of corrosion, and exhibit superior resistance to the conduction of electrical current.

1.8 Composite Matrix Material Applications

The following are common application areas of composite matrix materials:

- Electrical moldings.
- Decorative laminates.
- High performance Cookware.
- Sealants and gaskets.

- Heat shield systems (capable of handling high temperatures, thermal shock conditions and heavy vibration).
- Components for high-temperature gas turbines such as combustion chambers, stator vanes and turbine blades.
- Brake disks and brake system components used in extreme thermal shock environments.
- Components for slide bearings under heavy loads requiring high corrosion and wear resistance.

1.9 Long fibre-reinforced composite materials

1. Glass fibres.
2. Carbon fibres.
3. Boron fibres.
4. Ceramic fibres.
5. Metal fibres.
6. Aramid fibres.
7. Natural fibres: sisal, hemp, flax, etc.

1.9.1 Glass fibers

Glass fiber (or glass fibre) is a material consisting of numerous extremely fine fibers of glass.

Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fiber reinforced composites are used in marine industry and piping industries because of good environmental resistance, better damage tolerance for impact loading, high specific strength and stiffness.

Figure 1.3 Glass Fiber mat

1.9.2 Carbon fibre

Carbon fibers or carbon fibres (alternatively CF, graphite fiber or graphite fibre) are fibers about 5 to 10 micrometers (0.00020–0.00039 in) in diameter and composed mostly of carbon atoms. Carbon fibers have several advantages: high stiffness, high tensile strength and high strength to weight ratio, high chemical resistance, high-temperature tolerance, and low thermal expansion. These properties have made carbon fiber very popular in aerospace, civil engineering, military, motorsports, and other competition sports. However, they are relatively expensive compared to similar fibers, such as glass fiber, basalt

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fibers, or plastic fibers.

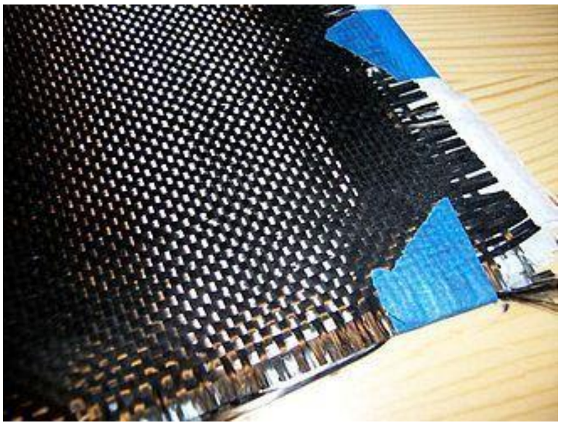

Figure 1.4 Carbon fiber mat

1.9.3 Boron fibre

Boron fibers are very stiff and have a high tensile and compressive strength. The fibers have a relatively large diameter and do not flex well; therefore, they are available only as a prepreg tape product. An epoxy matrix is often used with the boron fiber. Boron fibers are used to repair cracked aluminum aircraft skins, because the thermal expansion of boron is close to aluminum and there is no galvanic corrosion potential.

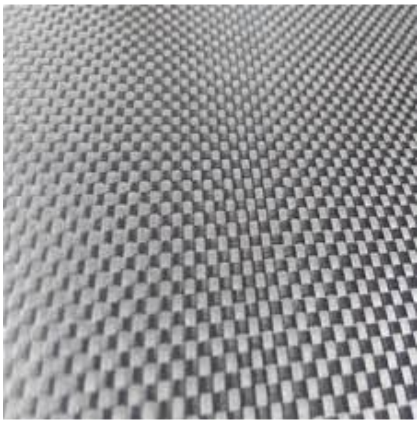

Figure 1.5 Boron fiber mat

1.9.4 Ceramic fibre

Ceramic fibres are small-dimension filament or thread composed of a ceramic material, usually alumina and silica, used in lightweight units for electrical, thermal, and sound insulation. The use of ceramic fibers in the composite applications is taking attraction/attention since the last decades. In particular, continuous ceramic fibers/filaments are generally employed in high-temperature applications instead of metals due to their high thermal tolerance and corrosion resistance. Ceramic fibers may be produced in various forms like blankets, felts, bulk fibers, vacuum-formed or cast shapes, paper, and textiles depending on the application area.

Figure 1.6 Ceramic fiber mat

1.9.5 Metal fibre

Metal fibers include nowadays fibers which are produced of pure metals, alloys, or metalloids after different mechanical and thermal production processes. Metal fibers are produced as thin filaments with diameters ranging from 1 to 80 µm. Among the various forms are chopped fibers and needle felt. Chopped fibers can be used in wet laid operations. Needle felt forms composed of or containing metal fibers are often sintered to produce a stiff rigid media. Metal fibers are produced from a variety of metal alloys.

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Figure 1.7 Metal fiber mat

1.9.6 Aramid fibre

Aramid fibers, short for aromatic polyamide, are a class of heat-resistant and strong synthetic fibers. They are used in aerospace and military applications, for ballistic- rated body armor fabric and ballistic composites, in marine cordage, marine hull reinforcement, and as an asbestos substitute. The chain molecules in the fibers are highly oriented along the fiber axis. As a result, a higher proportion of the chemical bond contributes more to fiber strength than in many other synthetic fibers. Aramids have a very high melting point (>500 °C).

Figure 1.8 Aramid Fiber mat

1.9.7 Natural fibres

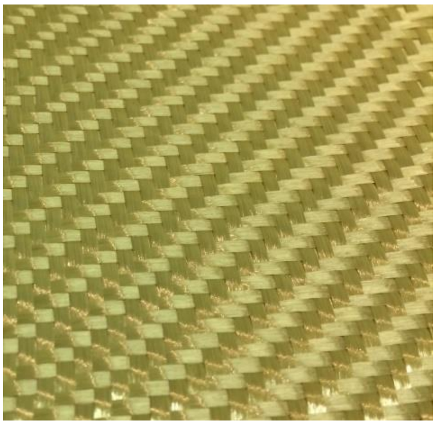
Natural fibres can be classified according to their origin. The vegetable, or cellulose- base, class includes such important fibres as cotton, flax, and jute. The animal, or protein-base, fibres include wool, mohair, and silk. An important fibre in the mineral class is asbestos. The vegetable fibres can be divided into smaller groups based on their origin within the plant. Cotton, kapok, and coir are examples of fibres originating as hairs borne on the seeds or inner walls of the fruit, where each fibre consists of a single, long, narrow cell. Flax, hemp, jute, and ramie are bast fibres, occurring in the inner bast tissue of certain plant stems and made up of overlapping cells.

Figure 1.9 Types of Natural fibers & its representation

METHODOLOGY

3.1 General

In this chapter, the fabrication of composite plate is displayed. Fibers namely glass and palm fibers are used to fabricate the composite plate. The two fibers are one is synthetic fiber and the other one is natural fiber. These fibers are taken in the form of UD mat. And are bonded together using LY 556 and HY 951 epoxy. The fibers are procured from



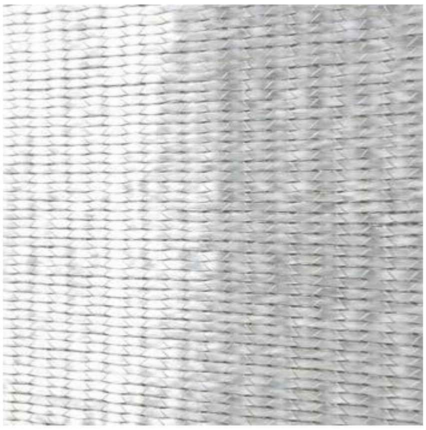
Arrow technical textiles private limited and the epoxy from Sree industrial composites private limited. These are displayed in the below images.'

3.2 Materials

The materials taken in the project are Glass fibres, Palm fibers and Epoxy. Glass and plam fibers are taken in the form of UD MAT and they were cut into 200/200mm in length and breadth. Five layers are taken for each specimen.

3.2.1 Glass fiber

Glass fiber is formed when thin strands of silica-based or other formulation glass are extruded into many fibers with small diameters suitable for textile processing. The technique of heating and drawing glass into fine fibers has been known for millennia, and was practiced in Egypt



and Venice.

Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fiber reinforced composites are used in marine industry and piping industries because of good environmental resistance, better damage tolerance for impact loading, high specific strength and stiffness.

3.2.2 Palm fiber

Oil palm fiber is equivalent to coconut fiber at a competitive price. Oil palm fiber is non-hazardous biodegradable material extracted from oil palm's empty fruit bunch (EFB) through decoration process. The fibers are clean, non-carcinogenic, and free from pesticides and soft parenchyma cells. Palm fibers are versatile and stable and can be processed into various dimensional grades to suit specific applications such as mattress cushion production, erosion control, soil stabilization/compaction, landscaping and horticulture, ceramic and brick manufacturing, thermoplastic filler, flat board manufacturing, paper production, acoustics control, livestock care, compost,

fertilizer, animal feed, etc…

The oil palm fiber is produced from empty fruit bunch that are considered as waste after the extraction oil palm fruits. To become the useable fiber, the empty fruit bunches goes through process which involve empty fruit bunches to be shredded, separated, refined and dried. No chemicals were involved in the production of oil palm fibers. High quality oil palm fibre is clean and toxic free. After the process, the end product of high quality oil palm fiber can be used by manufactures to make various fiber composites such as furniture's, infrastructures, mattress, erosion control, paper production and also landscaping.

Figure 3.1 Glass fiber UD mat

Figure 3.2 Palm fiber UD mat

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Figure 3.3 LY 556

Figure 3.4 HY 951

3.3 Tools Used

Figure 3.5 Transparent sheet

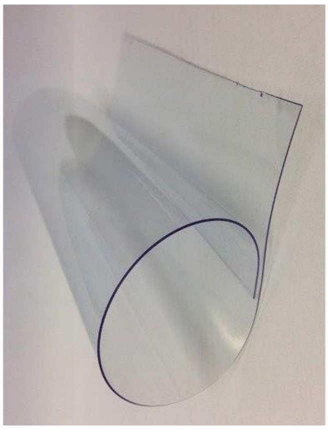

Figure 3.6 Wax polish

Figure 3.7 Weighing balance

Figure 3.8 Mug

Figure 3.9 Stirring rods

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Figure 3.10 Squeezers

Figure 3.11 Brush

Figure 3.12 Mug with brush

3.4 Fabrication Method

There are numerous methods for fabricating composite components. Some methods have been borrowed (injection molding from the plastic industry, for example), but many were developed to meet specific design or manufacturing challenges faced with fiber-reinforced polymers. Selection of a method for a particular part, therefore, will depend on the materials, the part design and end-use or application.

Composite fabrication processes typically involve some form of molding, to shape the resin and reinforcement. A mold tool is required to give the unformed resin/fiber combination its shape prior to and during cure. Click on “Tooling” for an overview of mold types as well as materials and methods used to make mold tools.

3.4.1 Types of Fabrication Methods

1) Manual hand layup
2) Automatic lay
3) Open Contact
4) Resin Transfer Molding (RTM)
5) Vacuum-Assisted Resin Transfer Molding (VARTM)
6) Resin Film Infusion (RFI)
7) Compression and Injection Molding

3.4.2 Manual Hand layup method

Figure 3.13
Mixing of hardener and softener
Mixing of hardener and softener

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Figure 3.15

Figure 3.16
Applying epoxy on the glass layers
Applying epoxy on the palm layers

Figure 3.17 Squeezing operation

The manufacturing process known as 'hand layup' involves manually laying down individual layers or 'plies' of a form of reinforcement known as 'prepreg'. This consists of thousands of fibers, which are pre-impregnated with resin and bundled into tows and arranged either in a single unidirectional ply or woven together.

Simple, low cost, open mold fabrication process using liquid epoxy resin to position layers of laminations in a mold until desired shape/thickness is achieved. Woven such as plain, twill, plain basket waves, knitted, stitched bonded fabric layers are impregnated with an appropriate epoxy resin system by brush or roller to ensure high quality composite components/parts meet specific end user requirements. Vacuum bagging can be placed over the lay-up to assure no air entrapment or voids during polymerization.

Room temperature, heat (oven) and autoclave curing products are available for processing low, medium, high production needs. Heat cure systems should be deliberately ramped up and down in temperature to prevent distortions/war page from uneven expansion/contraction. Secondary posture process will enhance/maximize composite performance capability. Usage extends from wind turbine blades, auto/bus parts, aircraft components, structural panels, air handling equipment, housing, and marine systems.

3.4.3 Final fabricated sheet weight

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Figure 3.19 Figure 3.20
First plate weight = 477gms Second plate weight = 486gms

Figure 3.21

Figure 3.22
Third plate weight = 296gms Fourth plate weight = 310 gms

Figure 3.23

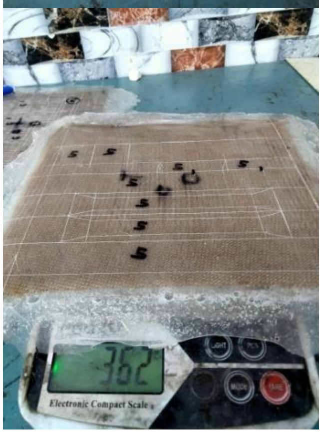

Figure 3.24
Fifth plate weight = 362gms Sixth plate weight = 384gms

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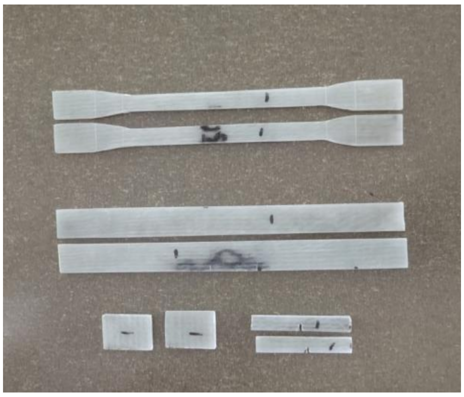
Figure 3.25

Figure 3.26

Seventh plate weight = 410gms

Eight plate weight = 408gms



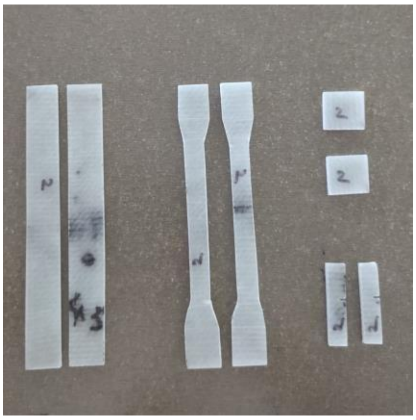


Figure 3.27 Specimen 1

3.5 Specimen preparation – calculation

Here, the composite is manufactured and cut into small specimens. Glass and palm are having eight different combinations and each combination has 5 layers namely as follows and also each specimen is cut in to our required standards. There are eight specimens are fabricated in this project namely

1) Specimen1-Glass fiber reinforced composite with 0/30
2) Specimen2-Glass fiber reinforced composite with 0/45
3) Specimen3-Palm fiber reinforced composite with 0/30
4) Specimen4-Palm fiber reinforced composite with 0/45
5) Specimen5-Glass Palm reinforced Hybrid composite with 0/30/90/-30/0
6) Specimen6-Glass Palm reinforced Hybrid composite with 0/45/90/-45/0
7) Specimen7- Palm Glass reinforced Hybrid composite with 0/30/90/-30/0
8) Specimen8-Palm Glass reinforced Hybrid composite with 0/45/90/-45/0

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Figure 3.28 Specimen 2

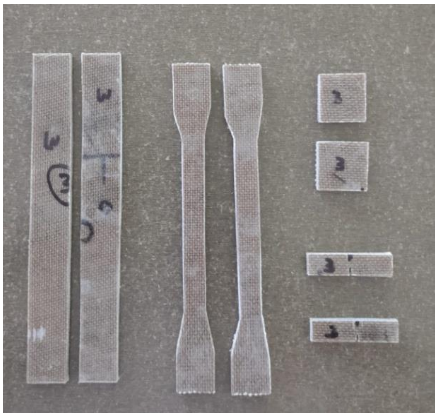

Figure 3.29 Specimen 3

Figure 3.30 Specimen 4

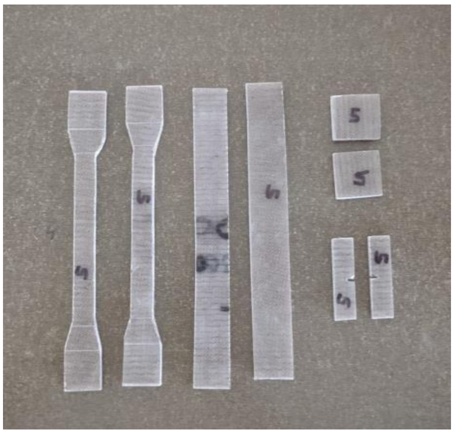

Figure 3.31 Specimen 5

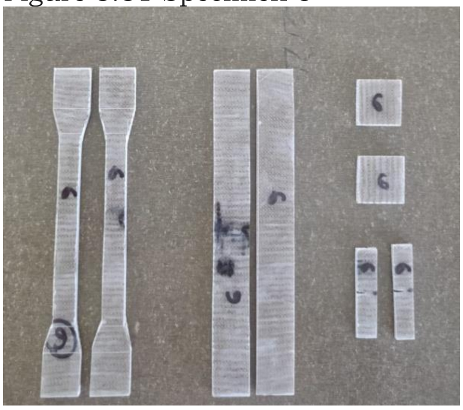

Figure 3.32 Specimen 6

3.5.1 Fiber orientation

In this we take two orientations with different combinations like (0/30), (0/45).

Specimen 1 – G+G+G+G+G – 0/30/90/-30/0 – 248gms

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Figure 3.36

5-layers-248gms Epoxy -310gms

Specimen 2 – G+G+G+G+G - 0/45/90/-45/0 – 236gms

Figure 3.37

5-layers-236gms Epoxy-301gms

Specimen 3- P+P+P+P+P- 0/30/90/-30/0 - 69gms

Figure 3.38
5-layers-69gms Epoxy -207gms

Specimen 4- P+P+P+P+P- 0/45/90/-45/0 - 68gms

Figure 3.39
5-layers-68gms Epoxy -204gms

Specimen 5 - G+P+P+P+G – 0/30/90/-30/0- 229.8gms
Glass fiber – 0/0 – 94gms
Palm fiber – 30/90/-30 – 39gms

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Figure 3.40

Figure 3.41
2-layers-94gms Epoxy -229.8 3-layers-39gms Epoxy - 229.8gms

Specimen 6 – G+P+P+P+G– 0/45/90/-45/0 – 229.8gms
Glass fiber - 0/0 - 94gms
Palm fiber - 45/90/-45 – 39gms

Figure 3.42 Figure 3.43
2-layers-94gms Epoxy -229.8 3-layers-39gms Epoxy - 229.8gms

Specimen 7– P+G+G+G+P– 0/30/90/-30/0 – 259.2gms
Palm fiber - 0/0 - 30gms
Glass fiber - 30/90/-30 – 141gms

Figure 3.44

Figure 3.45
2-layers-30gms Epoxy-259.2gms 3-layers-141gms Epoxy-259.2gms
Specimen 8– P+G+G+G+P– 0/45/90/-45/0 – 229.8gms
Palm fiber - 0/0 - 27gms

Glass fiber - 45/90/-45 – 131gms
Figure 3.46
2-layers-27gms Epoxy- 238.2gms 3-layers-131gms Epoxy-238.2gms

3.5.2 Calculations Specimen 1

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Fiber Weight (0/30/90/-30/0) = 248gms
Fibers to epoxy ratio= 1:1.2
248/2=124/2=62
62+248=313
Epoxy = 313gms
Specimen 2
Fiber Weight (0/45/90/-45/0) = 236gms
Fibers to epoxy ratio= 1:1.2
236/2=118/2=59
59+236=295
Epoxy = 295gms
Specimen 3
Fiber Weight (0/30/90/-30/0) = 69gms
Fibers to epoxy ratio= 1:3
69*3=207
Epoxy = 207gms
Specimen 4
Fiber Weight (0/45/90/-45/0) = 68gms
Fibers to epoxy ratio= 1:3
68*3=204
Epoxy = 204gms
Specimen 5
Glass fiber weight (0/0) = 94gms
Palm fiber weight (30/90/-30) = 39gms
Fibers to epoxy ratio for glass = 1:1.2.
Fibers to epoxy ratio for palm = 1:3
39*3= 117
94*1.2=112.8
=117+112.8
=229.8gms

Specimen 6
Glass fiber weight (0/0) = 94gms
Palm fiber weight (45/90/-45) = 39gms
Fibers to epoxy ratio for glass = 1:1.2.
Fibers to epoxy ratio for palm = 1:3
39*3= 117
94*1.2=112.8
=117+112.8
=229.8gms
Specimen 7
Palm fiber weight (0/0) = 30gms
Glass fiber weight (30/90/-30) = 141gms
Fibers to epoxy ratio for glass = 1:1.2.
Fibers to epoxy ratio for palm = 1:3
30*3= 90
141*1.2=169.2
=90+169.2
=259.2gms
Specimen 8
Palm fiber weight (0/0) = 27gms
Glass fiber weight (45/90/-45) = 131gms
Fibers to epoxy ratio for glass = 1:1.2.
Fibers to epoxy ratio for palm = 1:3
27*3= 81
131*1.2=157.2
=81+157.2
=238.2gms

3.6 Experimentation

To check the mechanical behavior of composite plates at different loading conditions. Different tests performed in the project are

1) Compression test
2) Hardness test
3) Surface roughness test

In the tensile test and compression test we get the tensile behavior and compression behavior. And in the hardness test we check the hardness at different value of various points on the surface. In the surface roughness tester is used to quickly and accurately determine the surface texture or surface roughness of a material. A roughness tester shows the measured roughness depth (Rz) as well as the mean roughness value (Ra) in micrometers or microns (µm).

3.6.1 UTM-Compression testing machine

Composite compression testing methods provide a means of introducing a compressive load into the material while preventing it from buckling. Compression tests are performed for composite materials that are in the form of a relatively thin and flat rectangular test specimen such as laminate panels.
Compression testing is one of the most important tests to determine the behavior of composite materials. Mechanical properties of composite materials can be altered by giving a load to the composite materials, but the properties are difficult to measure directly by a compression test machine. A very important aspect of analysis and design of the rig or frame relates to the compression properties of materials caused by the load applied to the rig. The rig has to be mounted in a

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compression test machine to utilize the machine's capability of measuring load and displacement progression.
The data of load versus displacement will have to be converted into a stress–strain relationship. By calculating the stress–strain relationship, it will be used to determine the compressive strength and modulus of elasticity of the materials.
Compression testing is essential, insofar as the compressive strength of an FRP may be very different from its tensile strength. A major difficulty is that the use of flat, straight-sided coupons, while convenient from a practical point of view, may require a reduced gage length if buckling is to be avoided in uniaxial compression, depending on the nature of the specimen.

On the other hand, if the gage length is too short, the grips will significantly influence the results. Various test protocols have been proposed based on shear loading and end loading, as well as alternatives, such as the use of a planar specimen glued to the compressive surface of a sandwich beam deformed in bending. An increasingly popular approach is the combined loading compression (CLC) test method , which is based on a relatively small and easy-to-use test fixture that is suitable for both tabbed and untapped straight sided-specimens, and in which the specimen is both end loaded and loaded in shear, while the shear loading limiting crushing of the specimen ends by the end plates.

Figure 3.64 CTM Machine

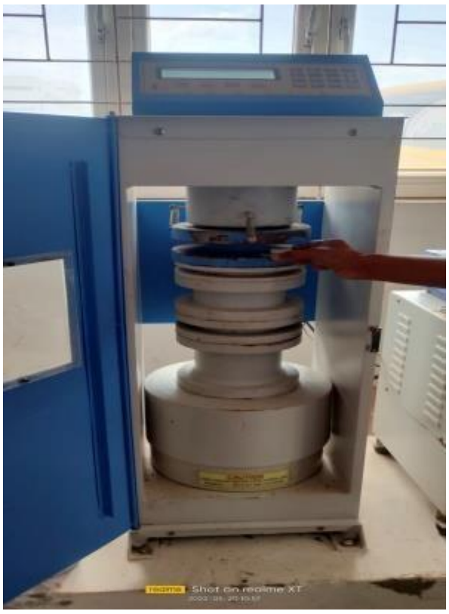

Figure 3.65 Specimen loading into CTM

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Figure 3.66 Specimen Loaded into CTM

Figure 3.67 Taking CTM readings 1

Figure 3.68 CTM readings – 2

from CTM

3.6.2 Hardness test

In this hardness testing machine there is two types of testing are there one is Rockwell hardness and another one is Brinell cum hardness testing. Here we perform Rockwell hardness test and at first we place the specimen on the anvil slowly lift the elevating screw by adjusting the hand wheel zero adjuster until the specimen is contact with the penetrator.

A constant load of 150kg is already adjusted inside the machine and the liver is slowly moved from unload condition to loading condition and wait for some dwell time (i.e. 5 sec) then slowly release the load from loading condition to loading condition. Then note down the spot 1 value and again take another two spots of the same surface and do the same procedure and note down the readings and like this remaining specimens were placed and performed the hardness test at various points. And finally we take the average value of each specimen and noted down in the tabular column.

The Rockwell hardness test method, as defined in ASTM E-18, is the most commonly used hardness test method. You should obtain a copy of this standard, read and understand the standard completely before attempting a Rockwell test.

The Rockwell test is generally easier to perform, and more accurate than other types of hardness testing methods. The Rockwell test method is used on all metals, except in condition where the test metal structure or surface conditions would introduce too much variations; where the indentations would be too large for the application; or where the sample size or sample shape prohibits its use.

The Rockwell method measures the permanent depth of indentation produced by a force/load on an indenter. First, a preliminary test force (commonly referred to as preload or minor load) is

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applied to a sample using a diamond or ball indenter. This preload breaks through the surface to reduce the effects of surface finish. After holding the preliminary test force for a specified dwell time, the baseline depth of indentation is measured.
After the preload, an additional load, call the major load, is added to reach the total required test load. This force is held for a predetermined amount of time (dwell time) to allow for elastic recovery. This major load is then released, returning to the preliminary load. After holding the preliminary test force for a specified dwell time, the final depth of indentation is measured. The Rockwell hardness value is derived from the difference in the baseline and final depth measurements. This distance is converted to a hardness number. The preliminary test force is removed and the indenter is removed from the test specimen.
Preliminary test loads (preloads) range from 3 kgf (used in the "Superficial" Rockwell scale) to 10 kgf (used in the "Regular" Rockwell scale). Total test forces range from 15kgf to 150 kgf (superficial and regular) to 500 to 3000 kgf (macro hardness).

Figure 3.48
Specimen under unload condition Specimen under loading condition

Figure 3.50 Person 1 operating the machine
The specimens used in surface hardness test is shown below

Figure 3.52 Specimen 1

Figure 3.53 Specimen 2

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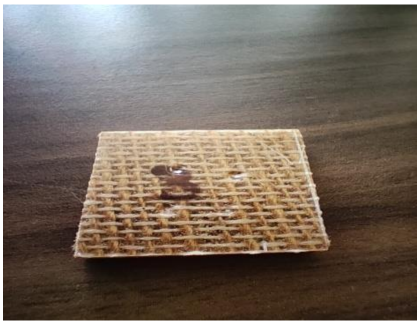

Figure 3.54 Specimen 3

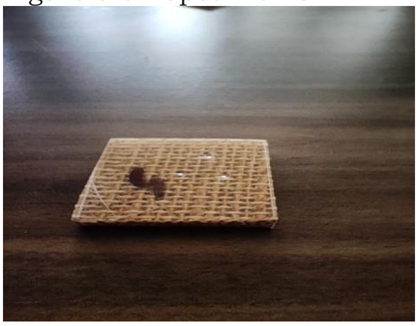

Figure 3.55 Specimen 4

3.6.3 Surface roughness test

A stylus instrument measures in two dimensions, recording the height at every point along a line. Other instruments, such as optical profilers, can measure in three dimensions, acquiring an entire area of data in just a few seconds. For 3D measurements we use “Sa” as the areal/3D equivalent to Ra (two-dimensional) average roughness. In this surface roughness test, the machine is placed on the flat surface. The specimen is placed under the stylus and holds the specimen while measuring the surface, the Ra and Rz values are shown on the LED screen and note down the values. The same procedure is done for remaining 7 specimens to note down the Ra and Rz values. A roughness tester is used to determine the surface texture or surface roughness of a material. A roughness tester shows the measured roughness depth (Rz) as well as the mean roughness value (Ra) in micrometers or microns (μm). Ra value tells us average roughness is a good first-pass indicator of the overall height of the surface texture. For decades it has proven useful for tracking manufacturing processes in industries from automotive to medical devices. It can be measured quickly using only inexpensive gauges, making it an effective tool for shop floor quality control. Here the specimens which are used for hardness testing, that the same specimens is used in this surface roughness also.

RESULTS & DISCUSSION

4.1 General

This chapter contains mechanical characterization results and surface characterization results of the fabricated composite plate. The fabricated composite plates are taken with cross play of 0/30 and 0/45 lay-up and 0/30 and 0/45 orientation. So mechanical characterization performed is CTM test and surface characterization such as surface roughness and surface hardness.

4.2 Mechanical Characterization

Here we performed three tests one mechanical characterization and two surface characterizations. In the mechanical characterization we find the compression strength. In the surface characterization we check hardness and surface roughness. We check surface roughness on both top and bottom layers and for the surface hardness test we performed test only for top layer. Mechanical characterization is performed on compression testing machine (CTM) the fabricated eight composite plates are tested for CTM and the results were displayed below.

4.2.1 Compression testing (CTM) results

We have taken each specimen of size 3x3 was fabricated with the thickness of 0.5mm. The composite plate is then placed in the CTM machine and then compressed up to maximum compression strength. The maximum

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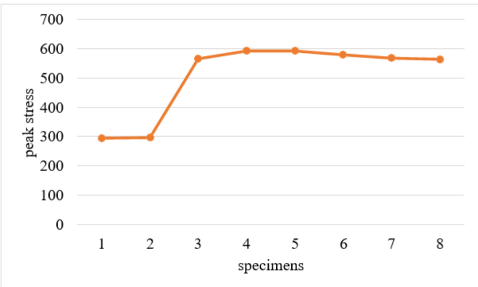
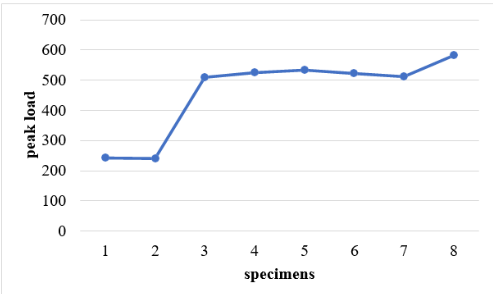
compression strength is found is 582.2KN. The maximum compression is found for specimen 1 is 0.3mm. The maximum compression is found for specimen 2 is 0.2mm. The maximum compression is found for specimen 3 is 0.3mm. The maximum compression is found for specimen 4 is 0.3mm. The maximum compression is found for specimen 5 is 0.3mm. The maximum compression is found for specimen 6 is 0.3mm. The maximum compression is found for specimen 7 is 0.3mm. The maximum compression is found for specimen 8 is 0.3mm.

4.2.2 Experimental values – CTM

Specimen	Area	Peak load	Peak stress
Specimen1	9.0square cm	608.7KN	0.30mpa
Specimen2	9.0square cm	240.8KN	297.28mpa
Specimen3	9.0square cm	510.0KN	566.66mpa
Specimen4	9.0square cm	525.2KN	593.23mpa
Specimen5	9.0square cm	533.6KN	592.88mpa
Specimen6	9.0square cm	522.1KN	580.11map
Specimen7	9.0square cm	511.9KN	568.77mpa
Specimen 8	9.0square cm	582.2KN	564.88mpa



Graph 4.1 (CTM Peak stress)



Graph 4.2 (CTM Peak load)

Finally we observed that maximum peak load is seen in the specimen 8 is 582.2KN and the maximum peak stress is observed in specimen 4 is 593.23mpa.

4.3 Surface Characterization

4.3.1 Surface Hardness

In this hardness testing machine there is two types of testing are there one is Rockwell hardness and another one is Brinell cum hardness testing. Here we perform Rockwell hardness test and at first we place the specimen on the anvil slowly lift the elevating screw by adjusting the hand wheel zero adjuster until the specimen is contact with the penetrator. A constant load of 150kg is already adjusted inside the machine and the liver is slowly moved from unload condition to loading condition and wait for some dwell time (i.e. 5 sec) then slowly release the load from loading condition to loading condition. Then note down the spot 1 value and again take another two spots of the same surface and do the same procedure and note down the readings and like this remaining specimens were placed and performed the hardness test at various points.

4.3.2 Experimental results – Surface Hardness

SPECIMEN	SPOT 1	SPOT 2	SPOT 3	Average
Specimen 1	47	28	41	38.6
Specimen 2	25	18	32	25
Specimen 3	30	42	26	32.6
Specimen 4	35	44	46	41.6
Specimen 5	41	30	25	32
Specimen 6	47	45	28	40
Specimen 7	32	30	24	28.6
Specimen 8	35	25	26	28.6

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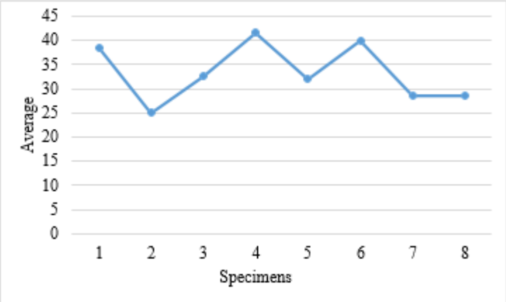

Graph 4.3 (hardness)

Finally, we observe that the surface hardness results indicate that 0/30 degree orientation for the glass had the highest value compared with the 0/45 degree orientation for palm fiber records the highest value compared to the 0/30 orientation.

4.3.3 Surface Roughness

Surface characterization such as surface roughness and surface hardness was performed on the eight fabricated specimens. Surface roughness was found on both layers and for surface hardness was found only for top surface taking three values as average.

4.3.4 Experimental Results – Surface Roughness

SPECIMEN	INDICATION	Ra	Rz
Specimen 1	TOP	0.451	1.277
	BOTTOM	2.279	6.448
Specimen2	TOP	3.673	10.38
	BOTTOM	1.319	3.731
Specimen 3	TOP	0.889	2.514
	BOTTOM	2.984	8.440
Specimen 4	TOP	1.514	4.282
	BOTTOM	3.233	9.143
Specimen 5	TOP	0.246	0.697
	BOTTOM	1.623	4.591
Specimen 6	TOP	1.260	3.564
	BOTTOM	4.449	12.58
Specimen 7	TOP	0.967	2.734
	BOTTOM	2.556	7.229
Specimen 8	TOP	0.407	1.153
	BOTTOM	1.670	4.724

Finally, we observe that the surface roughness is found for both top and bottom layers of the composite plate. The result for the surface roughness indicates that the Rz value found is 3X times the Ra value.

CONCLUSIONS

In this project, the hybrid composite plate was fabricated using the hand layup technique. Two fibers namely glass and palm were considered and epoxy LY 556 and HY 951 were considered to fabricate the plate. The specimens are then cut to ASTM D 638 standard to perform mechanical and surface characterization. The compressive strength was found for all the 8 fabricated specimens. Different configurations such as 0/30 and 0/45 with a standard layer orientation of 90 degrees at the middle considering the number of layers as 5, the plate was fabricated.

The compressive results indicate that the maximum compression strength is found is 582.2KN. The maximum compression is found for specimen 1 is 0.3mm. The maximum compression is found for specimen 2 is 0.2mm. The maximum compression is found for specimen 3 is 0.3mm. The maximum compression is found for specimen 4 is 0.3mm. The maximum compression is found for specimen 5 is 0.3mm. The maximum compression is found for specimen 6 is 0.3mm. The maximum compression is found for specimen 7 is 0.3mm. The maximum compression is found for specimen 8 is 0.3mm.

The hardness results indicate that the specimen 4, 6, 1 and 3 indicates high hardness compared to the other specimens. Also, we observe that the surface hardness results indicate that 0/30 degree orientation for the glass had the highest value compared with the 0/45 degree orientation for palm fiber records the highest value compared to the 0/30 orientation.

The surface roughness indicates for both top and bottom layers of the composite plate. The result for the surface roughness indicates that the Rz value found is 3X times the Ra value.

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