

MECHANICAL PROPERTIES AND MORPHOLOGICAL STUDY ON PALM FIBRE AND S-GLASS REINFORCED POLYMER MATRIX COMPOSITES

Submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering
degree in Mechanical Engineering

by

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DEPARTMENT OF MECHANICAL ENGINEERING

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade “A” by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of BOOBALAN. L (Reg. No. 37150037) and BENNET. S (Reg. No. 37150028) who carried out the project entitled **"MECHANICAL PROPERTIES AND MORPHOLOGICAL STUDY ON PALM FIBRE AND S-GLASS REINFORCED POLYMER MATRIX COMPOSITES"** under our supervision from November 2020 to March 2021.

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I, BOOBALAN. L (Reg. No.37150037) hereby declare that the Project Report entitled “**MECHANICAL PROPERTIES AND MORPHOLOGICAL STUDY ON PALM FIBRE AND S-GLASS REINFORCED POLYMER MATRIX COMPOSITES**” done under the guidance of **Dr. S. P. VENKATESAN, M.E., Ph.D.**, is submitted in partial fulfilment of therequirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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ABSTRACT

This investigation examine the polymer matrix composite material prepared from 32 wt% epoxy resin LY556 and 3 wt% hardener HY951 with Palm fibre (30 wt%, 20 wt%,10 wt%) and S-glass. Composite materials are made by reinforcing at least two materials of different properties. Hybrid Composite materials are framed by combining natural and synthetic fibres. In this study based on the physical, synthetic and mechanical properties of the chosen materials the necessary epoxy resin LY556 and hardener HY951 are picked and fabricated accordingly by using hand lay-up method. The test specimens are cut as per the ASTM standards using waterjet cutting. Different tests were conducted to assess the Mechanical properties like tensile strength, flexural strength, impact strength and hardness of the hybrid composite material. The morphological study used to identify the structure of the composite material is done by using scanning electron microscope. The elemental analysis also examined using SEM-EDX. The test results show that the specimen 1 (30 wt% palm fibre) which have the better strength, firmness, high strength to weight ratio and other mechanical properties compared to other specimens 2 (20 wt% palm fibre) and 3 (10 wt% palm fibre). The morphological properties show that the composite material have good bonding properties. The SEM-EDX analysis show that the composite material has 49.64% carbon which is a high strength element used for structural applications. Additionally, it has known that all hybrid composite materials are good alternative material for aerospace industries, building construction and automotive industries.

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CHAPTER-1

INTRODUCTION

1.1 MOTIVATION

The increasing use of fibre-reinforced polymer (FRP) composites in major load-bearing structures presents material scientists and structural engineers with many challenges. One of these challenges involves the understanding and prediction of the changes in the Mechanical properties and Mechanical properties responses of FRP composites under different concentration of Nano fillers. The progressive changes that occur in Mechanical properties and Dynamic Mechanical Analysis of FRP composites with glass fibre result from the alteration in the molecular structure of their polymer component.

A composite material is described as a mixture of at least two materials that has properties that are superior to those of the individual segments when used alone. Unlike metallic mixtures, each material has its own distinct structure, physical properties, and mechanical properties. Reinforcement and matrix are the two components. As compared to mass materials, the key advantages of composite materials are their high strength and stiffness combined with low density, resulting in a weight reduction in the finished part. The supporting stage offers stability and strength. The help is often harder, heavier, and stiffer than the system.

A fibre or a particulate is commonly used as reinforcement. Particulate composites have nearly equal dimensions in all directions. They may be circular, platelets, or some other shape with a normal or irregular shape. Particulate composites can be much more vulnerable and rigid than consistent fibre composites in general. The length of a fibre is much more significant than its calculation. The length-to-diameter (l/d) ratio is referred to as the perspective proportion, and it can vary greatly. Intermittent strands have short aspect ratios, while persistent filaments have long aspect ratios. Continuous fibre composites have a desired direction, whereas discontinuous fibre composites have an arbitrary direction.

Numerous modern technologies require materials with extraordinary blends of properties not found in the old style ceramics, metals, compounds, and polymeric materials of conventional designing. This especially applies to applications utilized submerged, and in aviation and transportation. A composite material is made up of a matrix and a type of reinforcement (particles, flakes, fibres, or fillers) (metal, polymer, or ceramic). The reinforcement keeps the matrix together to achieve the desired form, while the reinforcement increases the matrix's overall mechanical properties. Hybrid composites are composites of at least two forms of reinforcement in a matrix. The ability to combine the advantages of different reinforcement techniques to enhance performance while reducing cost and weight prompted the development of composite materials containing more than one type of fibre reinforcement (hybrid composites). Polymer is the most common matrix material used in such composite materials because of its strength and stiffness, which, although lower than metals and ceramics, can be enhanced by reinforcing with other materials; additionally, polymer matrix composite processing does not require high pressure or temperature. Polymer matrix composites are widely used synthetic composites. The utilization of polymers without support as underlying material is restricted by its low degrees of mechanical properties, yet building up the polymers with solid strands permits the manufacture of polymer lattice composites that offer more strength and firmness alongside protection from erosion. Their effectiveness is related to their low cost of manufacturing, high strength, and simple manufacturing principles. A A Karim, E E Kader, A A Hamod, A J Abdulrahman (2018) researchers explained.

1.2 DEFINITION OF COMPOSITE

The most generally utilized significance is the accompanying one, which has been expressed by J Artiz "Composites are multifunctional material frameworks that give qualities not realistic from any discrete material. They are durable constructions made by actually consolidating at least two viable materials, distinctive in synthesis and qualities and some of the time in structure". The shortcoming of this definition dwelled in the way that it permits one to arrange among the composites any combination of materials without showing either its particularity or the laws which should give it which recognizes it from other extremely cliché, unimportant blends.

Kelly unmistakably stresses that composites cannot be regarded literally as a combination of two materials. In terms of greater significance, the blend has distinct characteristics. It is better compared to both of the segments alone or deeply not the same as both of them in terms of solidarity to security from warmth or any other alluring quality.

Beghezan characterizes as "The composites are compound materials which contrast from alloys by the way that the individual segments hold their qualities however are so fused into the composite as to exploit just of their characteristics and not of their deficiencies", to acquire improved materials.

Van Suchetclan clarifies composite materials as heterogeneous materials comprising of at least two strong stages, which are in personal contact with one another on a minute scale. They can be likewise considered as homogeneous materials for a tiny scope as in any portion of it will have a similar physical property.

1.3 CHARACTERISTICS OF COMPOSITES

The mechanical properties of composites rely upon numerous factors, for example, fibre types, directions, and engineering. The fibre design alludes to the preformed material setups by meshing, sewing, or weaving. Composites are anisotropic materials with their strength being diverse toward any path. Their stress strain curves are straightly versatile to the place of disappointment by burst. The polymeric resin in a composite material, which comprises of viscus liquid and versatile solids, reacts visco flexibly to applied loads and also the viscoelastic material will creep and relax under a supported load, it very well may be intended to perform acceptably. Composites have numerous magnificent primary characteristics and a few models are high strength, material durability, fatigue endurance, and light weight. Other exceptionally attractive characteristics are high protection from raised temperature, abrasion, erosion, and chemical reactions. A portion of the benefits in the utilization of composite underlying individuals incorporate the simplicity of assembling, manufacture, dealing with, and erection. Undertaking conveyance time can be short. It took the Russell province engineer one day to introduce the deck boards in the principal vehicular composite scaffold. Composites can be defined and intended for elite, strength and broadened administration life. They have brilliant strength to-weight proportions. On the off chance that toughness can be demonstrated to most recent 75 years, composites can be financially advocated utilizing the life-cycle cost technique.

A portion of the burdens in the utilization of composites in spans are high originally cost, creep, and shrinkage. The preparation and construction of a project necessitates highly trained professionals. Natural deterioration of the composites, such as alkali attack and ultraviolet radiation exposure, is a possibility. There is no technology for joining or theoretically connecting. Due to the utilization of thin areas, there are worries in worldwide and local buckling. Although the light weight highlight might be a benefit in the reaction to earthquake loading, it could deliver the design aerodynamically unstable. In assembling with the conventional methods, there is a worry about the consistency of the material properties. The Zhang Y.H (2004), Radford K.C (1971) and Amdouni N (1992) scientist examined.

1.4 POLYMER MATRIX COMPOSITES

Polymers have both advantages (low cost, low density, ease of process) and disadvantages (poor mechanical properties) compared with other types of materials like metals and ceramics. One way to eliminate or mitigate these disadvantages is by producing polymer matrix composite materials. Regardless of the form of polymer, polymer matrix composites are much simpler to create than other composites (metal-matrix, ceramic-matrix, or carbon-matrix composites) (thermoplastic or thermoset). The explanation for this is that the polymers must be handled at relatively low temperatures. Normal processing temperatures for epoxy resins range from room temperature to 200°C; for thermoplastics such as polyether sulfone (PES) and polyimide (PI) the respective temperatures range from 300°C to 400°C.

PMCs are exceptionally mainstream because of their minimal effort and basic manufacture techniques. Utilization of non-supported polymers as construction materials is restricted by low level of their mechanical properties, specifically strength, modulus, and impact resistance. Reinforcement of polymers by solid fibrous network grants creation of PMCs, which is portrayed by the accompanying:

- a) High specific strength
- b) High specific stiffness
- c) High fracture resistance
- d) Good abrasion resistance
- e) Good impact resistance
- f) Good corrosion resistance
- g) Good fatigue resistance

1.5 DIFFERENT TYPES OF MATERIAL

1.5.1 *Plastics*

Plastics are of low thickness. They have great momentary synthetic obstruction yet they lack thermal stability and have just moderate protection from natural degradation. They have poor mechanical properties, however are effortlessly manufactured and joined.

1.5.2 *Ceramics*

Ceramics might be of low thickness. They have exceptional thermal stability and are resistant to the majority of attacks (corrosion, wear, abrasion). They are generally brittle and can be framed and shaped uniquely with difficulty, despite being naturally inflexible and solid due to their chemical bonding.

1.5.3 *Metals*

Metals have a density that varies from low to heavy. In this regard, only magnesium, aluminium, and beryllium can compete with plastics. Many other metals have greater thermal stability and can be alloyed to make them corrosion-resistant. Metals have excellent mechanical properties, are extremely tough, and are simple to form and join. It's mainly due to the metals' ductility and resistance to cracking.

1.6 FIBRE REINFORCED POLYMER COMPOSITES

The fibre is a significant constituent in composites. A lot of innovative work has been finished with the strands on the impacts in the sorts, volume portion, engineering, and directions. The fibre for the most part possesses 30%-70% of the matrix volume in the composites. The filaments can be slashed, woven, sewed, and additionally meshed. They are normally treated with sizing's like starch, gelatin, oil or wax to improve the bond just as fasteners to improve the taking care of. The most well-known kinds of filaments utilized in cutting edge composites for primary applications are the fibreglass, aramid, and carbon. The fibreglass is the most affordable and carbon being the costliest. The expense of aramid strands is about

equivalent to the lower evaluations of the carbon fibre. "Other high-strength high-modulus fibres, for example, boron is right now viewed as monetarily restrictive".

Regular fibre built up composites are made out of strands and a matrix. Fibres are the reinforcement and the fundamental wellspring of strength while matrix sticks every one of the strands together fit as a shape and moves stresses between the building up strands. The strands convey the loads along their longitudinal headings. In some cases, filler may be added to smooth the assembling interaction, impact exceptional properties to the composites, and/or diminish the item cost. Regular fibre supporting specialists incorporate asbestos, beryllium oxide, molybdenum, aluminum oxide, carbon/graphite filaments, beryllium, beryllium carbide, glass strands, polyamide, normal filaments and so on Likewise, normal network materials incorporate epoxy, polyester, polyurethane phenolic, polyetherethrketone (PEEK), vinyl ester and so on Among these tar materials, PEEK is most broadly utilized.

1.6.1 Glass fibres

Glass fibre are produced by bringing liquid glass into fine strings and afterward quickly shielding them from contact with the air or with hard surfaces to safeguard the imperfection free design that is made by the drawing process. Glass strands are just about as strong as any of the more up to date inorganic filaments however they need unbending nature by virtue of their molecular structure. Glass properties can be altered in part by modifying the glass's compound composition, but regular borosilicate glass, also known as E-glass, is the only glass used to any significant extent in composite materials.

Glass strands are divided into three categories, such as E-glass, S-glass, and C-glass. The E-glass is designated for electrical applications, while the S-glass is designated for high power. C-glass is known for its high corrosion resistance and is especially useful in structural design. S-Glass is commonly used for polymer matrix composites that require improved mechanical properties as compared to E-glass based composites in these three fibres. This is regularly the situation when the

material is worked under more outrageous conditions. S-Glass has a composition of SiO_2 65wt%, Al_2O_3 25wt%, MgO 10wt%. Some different materials may likewise be available at contamination levels.

1.6.2 Palm fibre

Customarily, palm fibres were utilized to make ropes for transport cordages which were demonstrated to have great properties in ocean water. The utilization of palm fibre has moved to another progressive level explicitly to different designing applications. The thickness of palm filaments is altogether lower than that of the well-known glass fibre, carbon fibre, and so on and furthermore invigorates 20% better specific strength. The elasticity and Young's modulus was altogether higher than some other normal filaments at any point explored. The high cellulose substance and lower lignin content guarantee better mechanical strength. Hence this portrayal results immovably affirms the chance of utilizing this fibre for the production of feasible fibre built up polymer composite.

1.6.3 Resin Systems

Another essential ingredient in composites is resin. The thermoplastics and thermosets are the two forms of resins. At room temperature, a thermoplastic resin maintains its power. When hot, it softens, and when cooled, it hardens. Long-chain polymers do not cross link in an artificial way. Since they don't fix for all time, they are bothersome for primary application. Then again, a thermosetting resin will fix for all time by irreversible cross connecting at raised temperatures. This trademark makes the thermoset resin composites entirely desirable for primary structural applications. The most widely recognized resins utilized in composites are the unsaturated polyesters, vinyl esters and epoxies; the most un-regular ones are the polyurethanes and phenolic.

1.6.4 Epoxy resin

The Epoxy Resin LY 556 is broadly utilized as a building up material because of its medium consistency and chemical resistivity. Property of this resin can without much of a stretch be altered inside wide cutoff points with the utilization of fillers and

hardeners. The arrangement of this resin depends on Bisphenol-A which makes it reasonable for elite FRP composite applications like pultrusion, pressure molding, fibre winding, etc. This LY 556 is known for uncommon mechanical, great fibre impregnation and thermal and dynamic properties. Likewise, the Epoxy Resin LY 556 is having a low propensity to take shape, that is the reason it is liked for airplane and aviation adhesives.

1.6.5 Hardener

The HY 951 Epoxy Hardener is blended in with epoxy resin for covering or embodying electronic segments which work at low voltages. This hardener is an unmistakable fluid with a flash point of 110 degrees centigrade, mix proportion 10:1 and specific gravity is 0.98 gm/cm³ at 25 degrees centigrade. The hardener is equipped for delivering medium-viscosity glues to bond ceramics, glasses, rubbers, plastics and different substrates. Blend this hardener with resin completely at room temperature. You can easily apply this hardener over the huge surfaces of substrates. The HY 951 Epoxy Hardener is having excellent mechanical strength, great resistivity against substance and atmospheric conditions.

1.7 SCOPE FOR REINFORCEMENT OF CONVENTIONAL MATERIALS

The composite matrix is needed to satisfy a few capacities, the vast majority of which are imperative to the performance of the material. Groups of strands are, in themselves, of little incentive to a specialist, and it is just the presence of a binder or matrix that empowers us to utilize them. The roles of the lattice in fibre-reinforced and particulate composites are very unique. The binder for a particulate total basically serves to hold the composite mass in a strong structure, however the matrix in a fibre composite plays out an assortment of different capacities which should be valued in the event that we are to comprehend the genuine composite activity which decides the mechanical behavior of a reinforced material.

1.7.1 Fibre-reinforced polymer (FRP)

It is the composite material made of a polymer matrix reinforced with strands. Glass, carbon, basalt, or aramid are the most common strands, though other filaments such as paper, wood, or asbestos have been used on occasion. The material is generally an epoxy, vinyl ester, or polyester thermosetting plastic, only phenol formaldehyde gums being used as of yet. FRPs are commonly used in the aerospace, automotive, marine, and construction industries. GRP stands for glass-reinforced plastic, which is a composite material or fibre-reinforced plastic made of fine glass filaments. The composite material is generally referred to as fibreglass, much like graphite-reinforced plastic. The glass may be a woven cloth or a chopped strand mat (CSM). Likewise, with numerous other composite materials (like reinforced concrete), the two materials act together, each conquering the shortages of the other. Though the plastic resins are strong in compressive loading and generally weak in elasticity, the glass strands are strong in tension however tend not to oppose pressure. By consolidating the two materials, GRP turns into a material that opposes both compressive and tensile forces well. The two materials might be utilized consistently or the glass might be explicitly positioned in those parts of the design that will encounter tensile loads.

1.8 ADVANTAGES OF COMPOSITES

FRP permits the arrangement of the glass strands of thermoplastics to suit explicit design programs. By indicating the direction of reinforcing fibres, the polymer's strength and resistance to deformation can be improved. While the fibres of glass reinforced polymers are parallel to the force being applied, they are the strongest and most resistant to deformation, and when the strands are perpendicular, they are the weakest. As a result, depending on the usage environment, this ability may be both a gain and a hindrance. Weak spots in perpendicular filaments may be used for natural hinges and links, but if the strands are not properly arranged to meet the expected forces, they can lead to material failure. The elasticity and strength of the polymer are not exactly the same as the matrix alone when forces are applied perpendicular to the

direction of strands. The path of strands can be put in two-dimensional and three-dimensional weaves in cast resin components made with glass reinforced polymers. This means that forces that are perpendicular to one direction correspond to forces in the opposite direction, eliminating the possibility of weak points in the polymer.

1.9 APPLICATIONS OF HYBRID COMPOSITES IN AUTOMOBILE ENGINEERING

The Composites have gotten favored material for weight decrease in vehicle. Hybrid composite materials are utilized in many designing applications for their adaptable properties like lightweight, strength to weight proportion, low cost, simplicity of construction advancement and high strength. Car industry uses composites and hybrid composites in a large number of the inside and outside applications. Thinking about simplicity of assembling strategies under the more extensive decision of manufacture methods, hybrid composites are grown any place it can contribute for the improvement of useful necessity essentially by replacing the current materials. Hybrid composites made by combining natural and synthetic fibres in a polymer matrix have a synergistic effect on properties that ordinary composites can't match. The development of various types of hybrid composites in automotive applications, such as car cylinders, brake friction material for medium-duty vehicles, and the improvement of environmentally friendly vehicles using hybrid composites are all underway.

1.10 ADVANTAGES OF GLASS FIBRE IN COMPOSITES

- Reinforcing fibres can enhance the polymer's strength and resistance to deformation.
- When the polymer fibres are parallel to the force being applied, glass reinforced polymers have more strength and resistance to deforming forces.
- Even after structural members have been seriously damaged due to loading conditions, it is possible to increase their strength.
- It will enhance flexural strengthening or shear strengthening.
- It will enhance Corrosion properties and chemical resistance of a material.

- Fibreglass products are built to last. Fibreglass has high resistance to fatigue and have an excellent durability over the last 50 years.

1.11 INDUSTRIAL TOOLING AND COMPOSITES

Epoxy frameworks are utilized in modern tooling applications to create molds, master models, overlays, castings, apparatuses, and other mechanical production components. This "plastic tooling" replaces metal, wood and other customary materials, and for the most part improves the proficiency and either brings down the general expense or abbreviates the lead-time for some modern processes. Epoxies are likewise utilized in delivering fibre-reinforced or composite parts. They are costlier than polyester resins and vinyl ester resins, however as a rule produce stronger and more temperature-safe composite parts.

1.12 OBJECTIVES

This research focuses on the changes that occur in the Mechanical properties, Morphological analysis and Elemental analysis in the SEM-EDX of the palm fibre and s-glass reinforced in the polymer matrix. Fibre reinforced composite materials are used as structural members in many applications like airplane. The main advantages of these materials are their high strength, stiffness and damping together with low specific weight. Experimental or analytical investigation on the hybrid composite material gives the different mechanical properties like Tensile strength which exhibits tensile properties of a material, Flexural strength which exhibits the flexural modulus of a material, Impact strength which exhibits the energy absorbed by the material and Hardness of a material which exhibits how hard the material is to be conducted. The morphological study using Scanning Electron Microscope to identify the topography of a material and SEM - Energy Dispersive X-Ray Spectroscopy is to be done for analyzing elements present in the fabricated hybrid composite material.

Based on the above analysis, the objectives of this research can therefore be defined as the following:

1. Fabrication of palm fibre and s-glass reinforced in the polymer matrix composite material by using hand layup method.
2. Evaluation of mechanical properties (tensile strength, flexural strength, impact strength, hardness of material).
3. To understand the morphological characteristics of a Hybrid composite material using scanning electron microscope.
4. To understand the elemental characteristics of a hybrid composite material using SEM – EDX.

CHAPTER- 2

LITERATURE SURVEY

In recent years hybrid composite material have evoked an unmistakable fascination for ongoing occasions for likely applications in "Aviation and automotive enterprises" attributable to their strength to weight ratio and temperature obstruction. The far and wide reception of particulate metal matrix composites for designing applications has been upset by the "Significant expense" of manufacturing components. One such measure is achieving a "Uniform distribution" of support within the matrix, which has a direct impact on the properties and nature of composite material.

Pandav P A (2017) and Sawant D A (2017) were considered the Experimental assessment and investigation of Glass Fibre Reinforced Composite under mechanical loading. They introduced the development and assembling of bike hub by utilizing epoxy resin and glass fibre composite material and compared the outcomes with traditional steel axle under various mechanical testing with assessing of various mechanical properties like rigidity, bending strength, impact strength, fatigue strength by utilizing appropriate experimental strategy.

Nishino T (2003) et al examined the composites show high mechanical and thermal properties, so they are broadly utilized in different applications from aviation to sports. These benefits, then again, can prompt natural issues in removal by incineration. In this way, to conquer these issues, there is distinct fascination for harmless to the ecosystem composites that utilize natural fibres as reinforcement.

Basheer A Alshammari (2019), Naheed Saba (2019), Majed D Alotaibi (2019), Mohammed F Alotibi (2019), Mohammad Jawaaid (2019) and Othman Y Alothman (2019) demonstrated that the Mechanical, Physical, and Morphological Properties are greater while using hybrid composite materials for structural applications.

Epoxy is an adaptable and generally accepted matrix material for creation of hardware segments, advanced composites, electrical circuit board materials and rocket equipment's, in view of its excellent bonding, thermal, mechanical, dielectric and maturing qualities. The Li et al (2011) and Chinnakannu K C et al (2007) researcher clarified.

Emad Al Hasani (2007) investigated the tensile strength and hardness properties of an epoxy (DGEBA) resin as a matrix reinforced with glass fibres for various volume fractions as layers, and discovered that the basic failure load could be increased depending on the number of layers.

Seal et al. (2001) investigated the mechanical properties of multilayer glass polymer composites. The structural characteristics of the deformation processes involved in the failure of commercial silica glass composites, multilayered glass epoxy composites, and glass disk–epoxy–E–glass fabric (GEF) composite materials were investigated.

Vaclav Bocek and Robert Vik (2008) were studied the Mechanical properties of Epoxy/Glass/Mica composites at high temperature. They had studied the mechanical, Electrical and thermal stresses of two different forms of cured epoxy/glass/mica composite.

Long-term Durability of Fibre-Reinforced Polymer-Matrix Composite Materials for Infrastructure Applications was investigated by Liao (1998). Likewise, he was examined that, a polymer matrix with E-glass fibre has incredible potential for supplanting steel rebar in concrete. At the point when strength is needed to some determination course of vehicle and so forth, fibre content proportion and fibre orientation are situation that shows the strength of composites is insufficient.

Jin-Woo Kim and Hyoung-Seok Kim (2012) looked at how fibre orientation and fibre quality influence the tensile strength of glass fibre-reinforced plastic. They also discovered that the tensile strength differed depending on the fibre material and fibre orientation.

Mechanical properties of palm fibre/glass fibre and epoxy mixed hybrid composite laminates were clarified by Raju K (2019) and Balakrishnan M (2019). They developed a polymer matrix composite with epoxy resin as a matrix reinforced with glass and palm fibre to minimize component weight while raising stiffness and strength for automotive applications. From the outcomes got it is noticed that by expanding the phase proportion of fibre particles the elasticity of the composite is expanded. From flexural test, it is presumed that hybrid fibre shows more benefit than the accessible composite. Additionally, hardness test addresses that the composite can be used for high strength to low weight applications. Then the prepared composite material is ecofriendly and also having the advantage of low cost.

Arikaran K (2018), Arockia Daniel Raj S (2018), Manigandan S (2018), Vijayasankar C (2018) Raju K (2019) are evaluated the mechanical properties of palm fibre and e-glass reinforced composite material. They have analyzed that the hybrid composite materials having weight reduction capabilities and high strength. They designed the spur gear for automobile applications using hybrid composites which have an advantage of low cost for manufacturing.

CHAPTER – 3

AIM AND SCOPE OF THE PROJECT

3.1 AIM OF THE PROJECT

In this project we aim to prepare a palm fibre and s-glass reinforced in the polymer matrix composite. Hybrid composites are new materials reinforced with glass fibres. These materials have a big potential for applications in the aerospace industry. They have a properties of decrease in weight, more hardness and high strength. Initially the palm fibre is reinforced with s-glass fibre. Epoxy resin and hardener is mixed using epoxy resin mixer. Hybrid composites are synthesized by hand lay-up method. Resin mixture is coated with polymer matrix for better surface adhesion. Casting technique is used to make the thick film with a required thickness of glass plate.

The mechanical properties of composites are predisposed mostly by the grip between matrix and fibres. The hybrid composite having palm fibre and s-glass was fabricated and its tensile strength, flexural strength, impact strength and hardness was investigated. The scanning electron microscopy is a most versatile technique used to identify the morphology of a samples. SEM analysis gives the microstructure and bonding differences of composites. Elemental analysis is carried out by using energy dispersive x-ray analysis.

In this study the hybrid composite material's mechanical properties, morphological study and elemental analysis are investigated. It shows the all hybrid composite material are good alternative material for aerospace industries, building construction, packing industries and automotive.

3.2 SCOPE OF THE PROJECT

The composite matrix is needed to satisfy a few capacities, a large portion of which are indispensable to the performance of the material. Packs of fibres are, in themselves, of little value to a specialist, and it is just the presence of a matrix or binder that empowers us to utilize them. The jobs of the matrix in fibre-reinforced and particulate composites are different. The binder for a particulate total essentially serves to hold the composite mass in a solid structure, yet the matrix in a fibre composite plays out an assortment of different capacities which should be valued in the event that we are to understand the genuine composite action which decides the Mechanical, Morphological Analysis and Elemental behavior of a reinforced material

- Fabrication of palm fibre and s-glass reinforced in the polymer matrix composite material by using hand layup method.
- Evaluation of mechanical properties (tensile strength, flexural strength, impact strength, hardness of material).
- To understand the morphological characteristics of a Hybrid composite material using scanning electron microscope.
- To understand the elemental characteristics of a hybrid composite material using SEM – EDX.

CHAPTER- 4

MATERIALS AND METHODS

4.1 MATERIALS

- Epoxy Resin (LY 556) is a base material on the glass plate, which is purchased from M/s. Sai Sakthi Enterprises, Saidapet, Chennai.
- Hardener (HY 951) is mixed with epoxy resin for coating, which is purchased from M/s. Sai Sakthi Enterprises, Saidapet, Chennai.
- S-Glass fibre 225 GSM – chopped strand mat which is used for reinforcement in polymer matrix purchased from M/s. Sai Sakthi Enterprises, Saidapet, Chennai.
- Palm fibre which is used for reinforcement in polymer matrix purchased from M/s. Go Green Products, Alwarthirunagar, Chennai.

4.1.1 *Epoxy Resin*

- Good adhesion properties, Good mechanical and physical performance.
- Flexible material, High corrosion resistance.
- The epoxy resin shown in figure 4.1.



Fig 4.1: Epoxy resin

4.1.2 Hardener

- It is mixed with epoxy resin in the ratio of 10:1 and having excellent mechanical strength.
- It has good resistivity against chemical & atmospheric conditions.
- The hardener shown in figure 4.2.



Fig 4.2: Hardener

4.1.3 Palm fibre

- It has low density when compared to synthetic fibres.
- Better mechanical strength.
- Subject to compliance with the appropriate temperature and humidity/moisture conditions.
- The palm fibre shown in figure 4.3.



Fig 4.3: Palm fibre

4.1.4 S-Glass Fibre

- Low co-efficient of thermal expansion
- High thermal conductivity
- High tensile strength- fibre glass yarn has a high strength to weight ratio
- White color
- The s-glass fibre shown in figure 4.4.



Fig 4.4: S-Glass fibre

4.2 METHODOLOGY

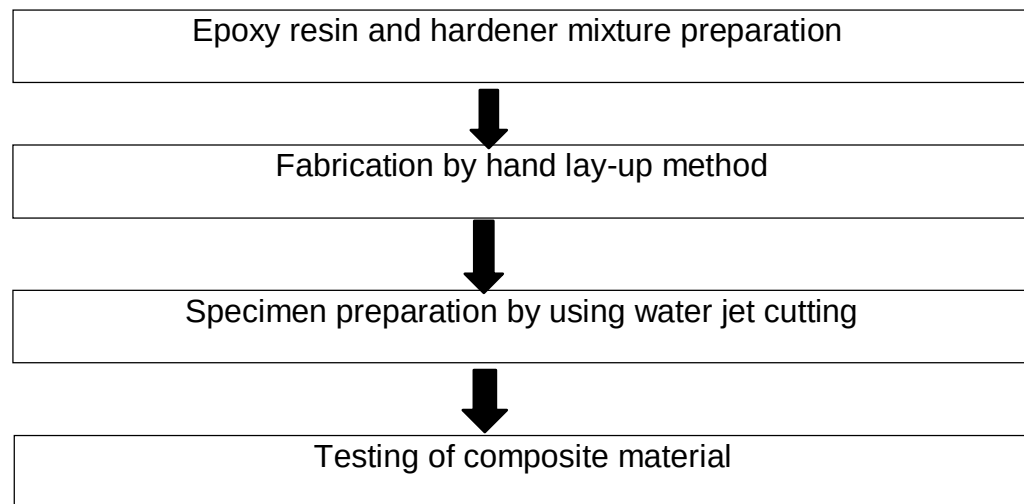


Fig 4.5: Flow chart for hybrid composite fabrication process

The figure 4.5 shows the methodology of hybrid composite material process.

4.3 PREPARATION OF EPOXY RESIN AND HARDENER MIXTURE

Epoxy resin and hardener mixture is used for fabrication of composite materials. The mixing ratio of epoxy resin and hardener is 10:1. Here the epoxy resin chosen for fabrication of hybrid composite is LY556 and the hardener is HY951. Initially the s-glass fibre is cut as per the mold size (30cm x 30cm). The weight of the s-glass fibre after cutting is 0.348 gram. The same weight of epoxy resin is measured and taken for mixing process. Then the hardener is measured and taken as per the mixing ratio (10:1). The weight of hardener is 0.034 gram. Finally, the epoxy resin and hardener is mixed as per the proportion for fabrication process. The figures 4.6, 4.7, 4.8 shows the preparation of epoxy resin and hardener mixture process.



Fig 4.6: Weight of s-glass fibre



Fig 4.7: Weight of epoxy resin



Fig 4.8: Weight of hardener

4.4 FABRICATION OF PALM FIBRE AND S-GLASS REINFORCED IN THE POLYMER MATRIX

The hybrid composites consist of palm fibre and s-glass is fabricated using hand lay-up method. Hand lay-up method is a widely used method for fabrication of composites. Most importantly, a release gel is showered on the mold surface to evade the adhering of polymer to the surface. Delivery wax is a substance specialist used to stop the holding of the molding material with mold. Gel coat gives you the smoothness needed for the composite product. It is normally a thin layer of resin that is around a few mm on the surface of the product. Mylar sheet is first applied above the mold for obtaining a high quality surface. S glass fibre is cut according to the mold size (30cm x 30cm). S glass fibre is manually put on the mold at this stage. After that, chopped palm fibre is put on top of s glass fibre.

Brushing is used to apply the laminating resin mixture. With the aid of a brush, the polymer is added gradually. After that, a second layer of glass fibre is applied to the polymer surface, and a roller is used to press down on the mat polymer layer to remove any trapped air. FRP rollers and paint rollers are used to solidify the cover, wetting the reinforcement fully and removing trapped air. The process is repeated with each subsequent layer until all of the necessary layers have been stacked. After curing at room temperature, the mold is opened, and the composite component formed is removed and treated further. This is known as sandwich construction. The three specimens were prepared with different palm fibre weight (30 wt%, 20 wt%, 10 wt%) accordingly.



Fig 4.9: Sandwich construction



Fig 4.10: Finished plate after curing

4.5 SAMPLE PREPARATION BY USING WATER JET CUTTING

A waterjet cutter is a mechanical device equipped for cutting a wide variety of materials utilizing an extremely high-pressure stream of water, or a combination of water and an abrasive substance. The word abrasive jet refers to cutting hard materials like metal, glass, or stone with a mixture of water and abrasive, while pure waterjet and water-only cutting refer to waterjet cutting without the addition of abrasives, which is typically used for soft materials like wood or rubber.

During the production of machine parts, waterjet cutting is commonly used. It is preferred technique when the materials being sliced are delicate to the high temperatures created by different methods, models incorporate plastic and aluminum. Waterjet cutting is utilized in different enterprises, including mining and aerospace, for cutting, reaming and shaping. Here we cut the samples as per the ASTM (American Society for Testing and Materials) standards. The waterjet pressure is maintained between 2500 bar to 4000 bar for machining the hybrid composite material. The figures mentioned below shows the specimens having different ASTM standards used for various mechanical testing.



Fig 4.11: Tensile test specimen ASTM-D638



Fig 4.12: Flexural test specimen ASTM-D790

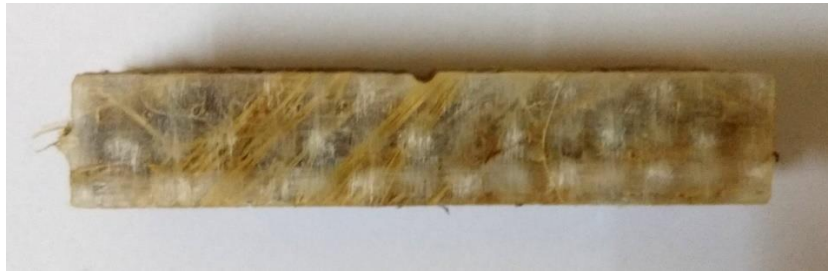


Fig 4.13: Impact test specimen ASTM-D256



Fig 4.14: Hardness test specimen ASTM-D785

CHAPTER – 5

RESULT AND DISCUSSION, PERFORMANCE ANALYSIS

5.1 MECHANICAL PROPERTIES AND PERFORMANCE OF HYBRID COMPOSITE MATERIAL

Tests of designing materials are exposed to a wide assortment of mechanical tests to quantify their strength, elastic modulus, and other material properties just as their performance under the different types of environment conditions and applications. The consequences of such mechanical and thermal tests are utilized for two basic roles: 1) Engineering design and 2) Quality control either by the materials maker to check the process or by the end client to affirm the material particulars. In view of the need to analyze estimated properties and performance on a common basis, clients and makers of materials utilize standardized test methods, for example, those created by the American Society for Testing and Materials, also known as ASTM and the International Organization for Standardization, also known as ISO. These guidelines specify how the test specimen will be prepared and examined, as well as how the test results will be investigated and published. Standards for nomenclature and terminology, as well as order and specification systems, exist. Mechanical measures in general, as well as tension, hardness, flexural, and impact tests in particular, are covered in the corresponding segments.

Mechanical experiments often include the deformation or breakage of test specimens, which are material samples. Note that test specimens are essentially engineering components that are subjected to a known stress or strain condition and the material properties are inferred from the mechanical response. For example, strength is simply a stress "at which something happens," whether it's the start of nonlinearity in the stress-strain response of yield strength, the maximum applied stress for ultimate tensile strength, or the stress at which the specimen fully breaks for fracture strength.

5.1.1 Evaluation of Tensile Strength of hybrid composite material

Tensile strength is the maximum stress which the material can withstand when elongated or stretched before failing or breaking point. Tensile strength is different from the compressive strength. Brittle failure happens when certain materials fail due to a lack of plastic deformation. Plastic deformation and necking can occur in other metals prior to fracture. ASTM D 638-03 was used to assess the tensile strength. This test is carried out on specimens that are smooth. The dimension of the specimen is 165mm x 19mm and a uniaxial load is applied through both the ends. In the work, this test is performed in the universal testing machine and the results are used to calculate the tensile strength of composite samples. Here, the test is conducted on three samples and the results are being obtained.

Tensile test was performed on a tensile machine (M100) at room temperature, according to ASTM D 638-03, at a crosshead speed of 50 mm/min. The test specimens were cut from a waterjet cutting. The 3 specimens in each sample were tested to establish testing reproducibility and average values are given. Tensile modulus and tensile strength were evaluated from the stress-strain data. The method of particle aggregation, dispersion, and interaction between composite particles determine the properties of fabricated composite materials. The interaction of particles and polymers determines the thickness of the material.

Particle distance, according to M. Hara et al. (1998), plays a significant role in the interphase behaviour and properties of composites. The percentage of reinforcement content and specimen condition have an effect on the composites' tensile properties. As a result, two factors affect the composites' tensile strength: reinforcing particles help to improve the material's strength through simple load transfer, which is contingent on the bond interaction between the particle/matrix interface, and by regaining dislocation motion. The inhibition of plastic relaxation at particle/matrix interfaces by Manoj singala et al. The variations of tensile strength of palm fibre and s-glass hybrid composites were measured and they are given in Table 5.1.

The tensile strength of three specimens are shown in figure 5.1.

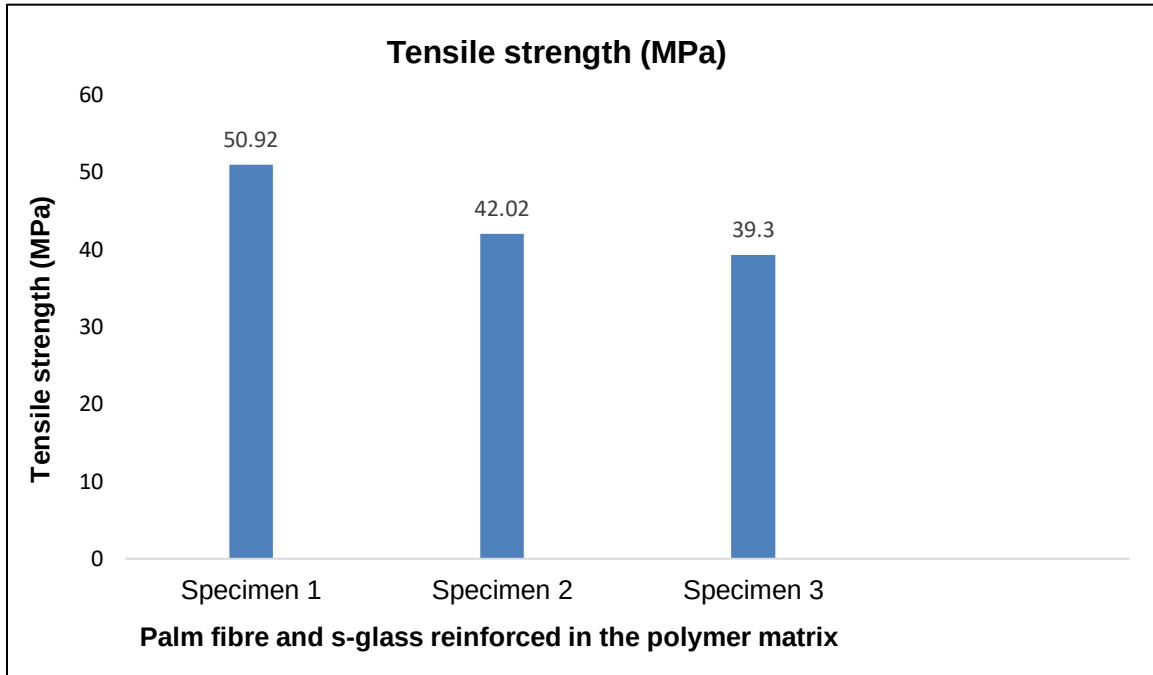


Fig 5.1: Tensile Strength

5.1.2 Evaluation of Flexural Strength of hybrid composite material

When the material undergoes the higher stress within the material the flexural strength is increase at its point of rupture. It is interpreted in terms of stress (σ). The maximum tensile stress that a composite can bear up to the breaking point is called its flexural strength. It will resist the bending force till the breaking point. Callister et al (2007), Vivlane et al (2006) and Zhao S et al (2008) explained the three-point bend test is performed on all the composite materials. The universal testing machine is used for the three-point bend test. The dimension of each specimen is 100mm x 12.7mm. Span length of 20 mm are maintained. The three-point bend test is conducted in all the composite materials for three times and the mean value is recorded. Ma J et al (2008) researcher studied the flexural strength of the composite specimen is determined using the following equation.

$$\text{Flexural strength} = (3PL/2bt^2)$$

Where, P is the full load (N), L is the specimen's span length (mm), b is the specimen's width (mm), and t is the specimen's thickness (mm). When two or more materials are mixed, the resulting composite material has a combination of properties that none of the individual components has, or although they achieve some intermediate properties between the two components, some components, especially durability, may be significantly superior in the composite compared to either of the two materials. The main function of fibres is generally to increase the strength and stiffness. They are translucent and have the physical properties required to withstand masticator forces. All the specimens are tested based on the ASTM-D 790 standard and the results are given in Table 5.1. Figure 5.2 shows the flexural strength of hybrid composite material.

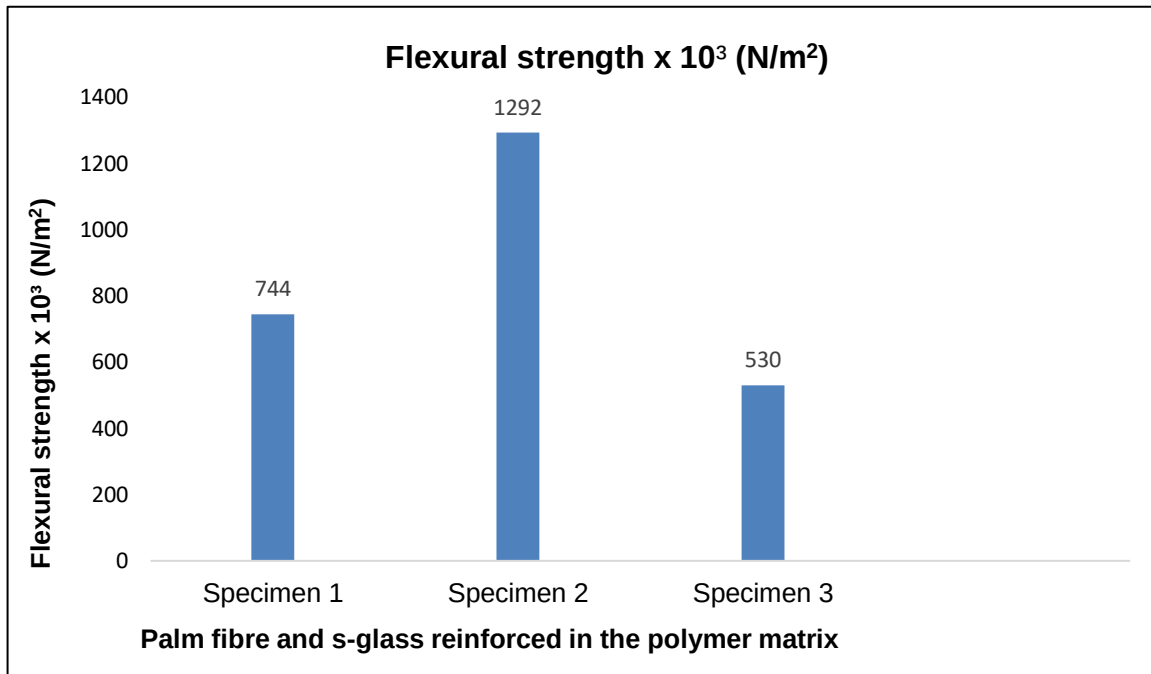


Fig 5.2: Flexural Strength

5.1.3 Evaluation of Impact Strength of hybrid composite material

The behavior of a material is depending on the rate at which the load is applied. Polymeric materials and metals which have low yielding point are highly impact to load application., For example, low-carbon steel shows increased yield strength with increasing the strain rate. The work hardening process is done at high-strain rates. This will give reduced local necking, so an overall material ductility is higher. Kovacevic V etal (2002) studied the explosive forming which is performed at the higher strain rates will be used for the fabrication of fibres at the required. When compared to conventional forming methods this method results in larger amounts of plastic deformation. Also, this method gives increased strength and dimensional stability to the part produced. The impact test is performed based on the ASTM D 256 standards. The impact test determines the material's ability to withstand a sudden shock when a load is applied. The impact measuring machine Izod is used for this test. The unit consists of a loading striker that has a fixed kinetic energy when released. The load will be released after the fabricated hybrid composite material is kept in the system. The amount of energy consumed will be shown on the dial. The dial indicator was used to record the impact energy of various specimens of hybrid composite materials.

The measured impact properties of palm fibre and s-glass reinforced in the polymer matrix composite are given in table 5.1. The figure 5.3 shows the variation of impact test of three specimens of hybrid composite material. The impact test is given by,

$$IS= EI/A \text{ Joules /mm}^2$$

Where EI- the impact energy in joules recorded on the scale, A - Area of the specimen in mm². In this test, the specimen should be in the measuring machine when the substance is being examined, and the pendulum should be allowed to swing until it hits the breaking point. The Izod impact test will easily calculate the amount of energy required to split the material. It's also used to determine the material's toughness and yield ability.

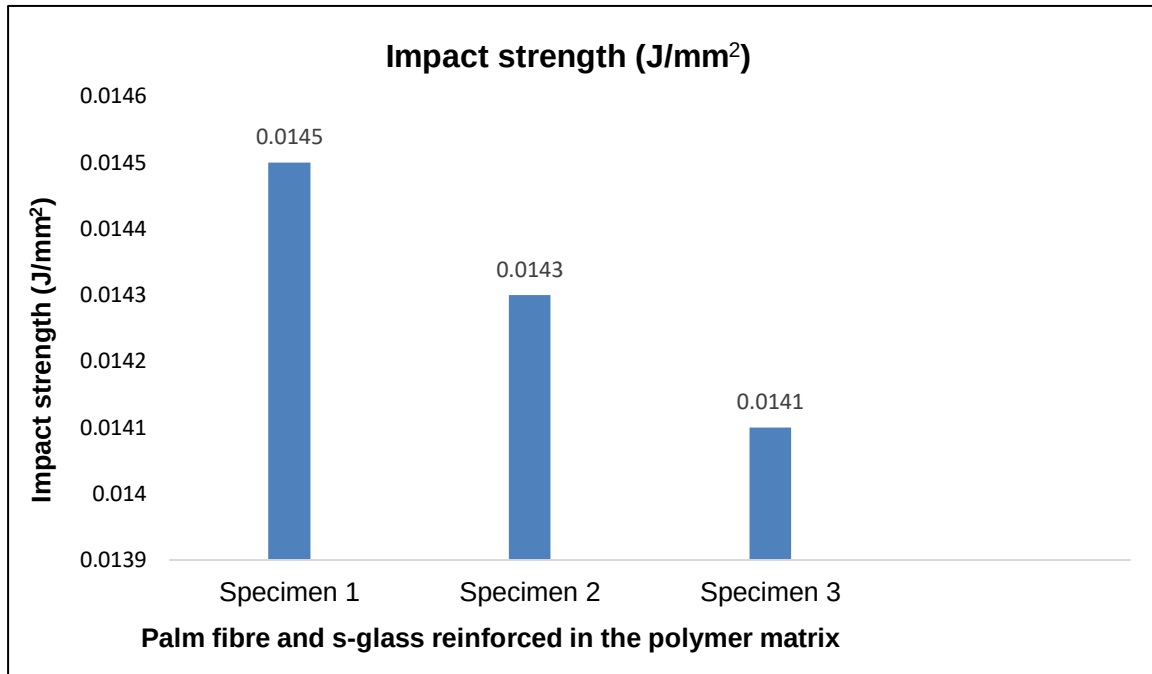


Fig 5.3: Impact Strength

5.1.4 Evaluation of Hardness of hybrid composite material

A material's hardness is a property that allows it to resist plastic deformation, most commonly by penetration. However, hardness may also apply to bending, scratching, cutting, or abrasion resistance. Dynamic Hardness Tester on the Go It's also used to test toughness in tight spaces, on massive and heavy materials, and on permanently mounted sections. For test material, the system has an underlying conversion facility to adjust the 'D' value to Vickers (HV), Rockwell (HRB, HRC), and Brinell (HB).

The Shore D Hardness test is performed based on the ASTM D2240 standards. The another standard for determining Shore D Hardness is ISO 868. the dimensions of the test specimen are 20mm x 20mm. The Durometer indenter foot is inserted into the sample for 15 seconds to determine the hardness value. Shore Hardness is a non-dimensional metric. It falls anywhere between 0 and 100. The measured hardness of palm fibre and s-glass reinforced in the polymer matrix composite are given in table 5.1.

The figure 5.4 shows the different Shore D Hardness values of the specimens.

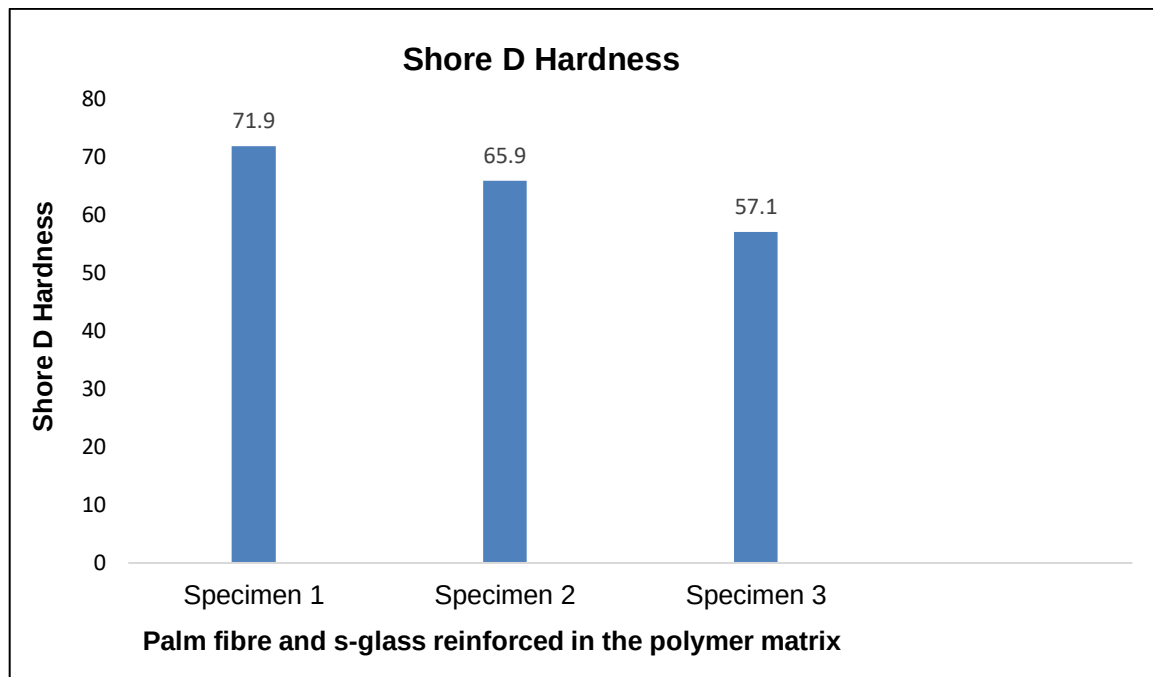


Fig 5.4: Hardness

Table 5.1: Mechanical properties of palm fibre and s-glass reinforced in the polymer matrix composite.

Specimens	Tensile Strength (MPa)	Flexural Strength x 10 ³ (N/m ²)	Impact Strength (J/mm ²)	Shore D Hardness
1	50.92	744	0.0145	71.9
2	42.02	1292	0.0143	65.9
3	39.30	530	0.0141	57.1

5.2 MORPHOLOGICAL STUDY OF HYBRID COMPOSITE MATERIALS

Fracture is a very important term which plays a big role of laminated materials. It is characterized as a process in which a sudden increase in loading causes pre-existing cracks to develop faster. The fracture surfaces of palm fibre reinforced polymer composites and s-glass reinforced polymer composites have been investigated. The SEM process was used to examine the broken surface of palm fibre and s-glass reinforced polymer matrix composites during a tensile examination.

A scanning electron microscope (SEM) is a type of electron microscope that uses a centered beam of electrons to scan the surface of an object and generate images. As electrons communicate with atoms in a sample, they produce a variety of signals that contain information about the sample's surface morphology and composition. The microscope used for scanning is Hi-Resolution Scanning Electron Microscope (HRSEM) - Thermoscientific Apreo S. The composite sample is cleaned appropriately and air dried. In a JEOL sputter ion coater, the sample was coated with 100Å thickness of platinum and observed under SEM at 15 kV. Until the micrographs are taken, a thin film of platinum is vacuum dissipated onto the composite sample to improve conductivity. The fracture surface morphology of the composite specimen is identified using SEM.

5.2.1 Scanning electron microscopy of hybrid composite material

The crack surfaces of the tensile test examples were inspected by using a scanning electron microscope (SEM). Figures 5.5, 5.6, 5.7 and 5.8 represents the SEM pictures of palm fibre and s-glass reinforced in the polymer matrix composite. The scanning electron microscope is used to investigate the surface morphology and microstructure of the hybrid composites. SEM also demonstrates the factors that decide earlier rupture during mechanical testing. Figure 5.5 presents a micrograph of hybrid composites at 200x magnification, disclosing their brittle plastic nature, with a glassy and Materials smooth exterior, having several stream-like crack. There are no clear gaps in between the pure palm fibre and s-glass particles. This proves that the palm fibre and s-glass had been mixed well during the fabrication process.

The Figures shows that information about the sample's surface morphology and composition of s-glass and palm fibre reinforced epoxy composite after composites fabrication. Via phase information of the fabricated composite specimens, the morphological properties of the fabricated composite surface show variation in mechanical properties. The distance between the sample surface and the lower end of the pole piece, from which the electrons are emitted, is known as the working distance. It's also known as "WD". Figure 5.6 show the SEM image of hybrid composite material at 650x magnification with working distance of 51.8mm. At 650x magnification with the working distance of 51.8mm it can be seen that large number of glass fibre which is reinforced with palm fibre were found, which indicates that high cohesive properties of glass fibre and palm fibre. Figure 5.7 show the SEM image of hybrid composite material at 650x magnification with working distance of 13.6mm. There were no clear gaps between the palm fibre and the s-glass in the SEM picture, indicating good interface bonding.

Figure 5.8 displays an 800x magnification SEM image of a hybrid composite content. The fibres were perfectly bound to the matrix at 800x magnification, and the fibres were also firmly imbedded in the matrix. This shows the mixing quality, which was due to a good interfacial contact between the palm fibre and the s-glass. This shows that stress is effectively transmitted between the fibres and the matrix polymer, resulting in increased tensile strength in response to stress.

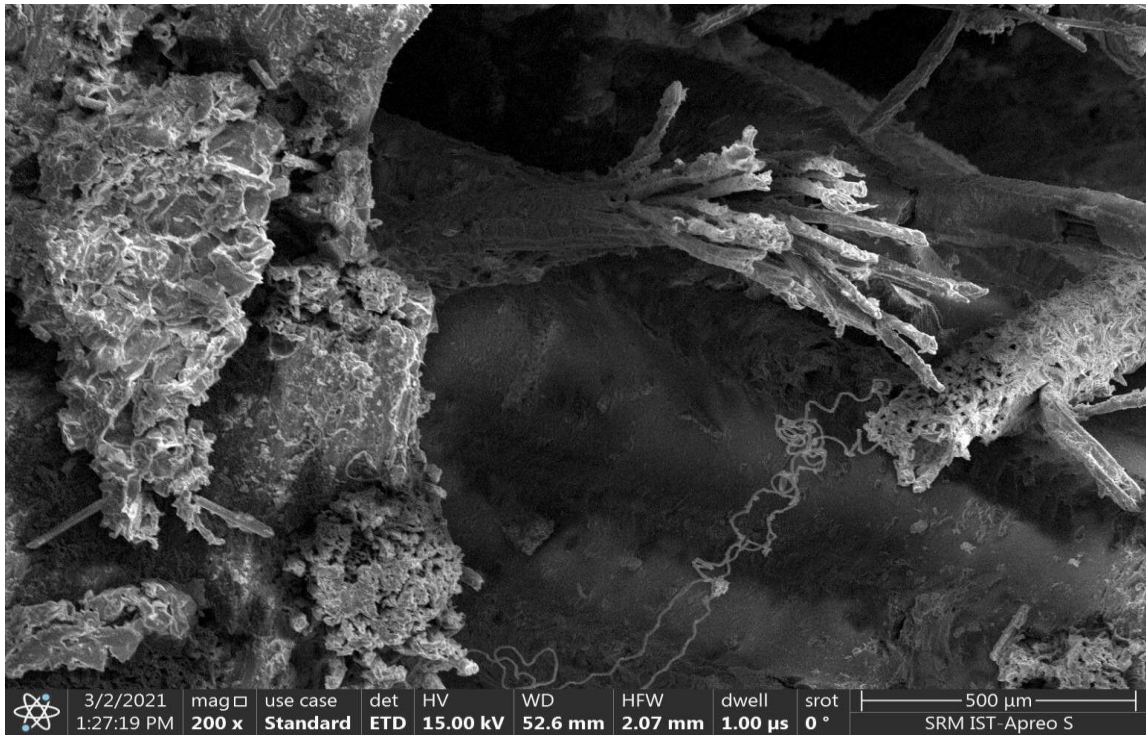


Fig 5.5: SEM image of hybrid composite material at 200x magnification

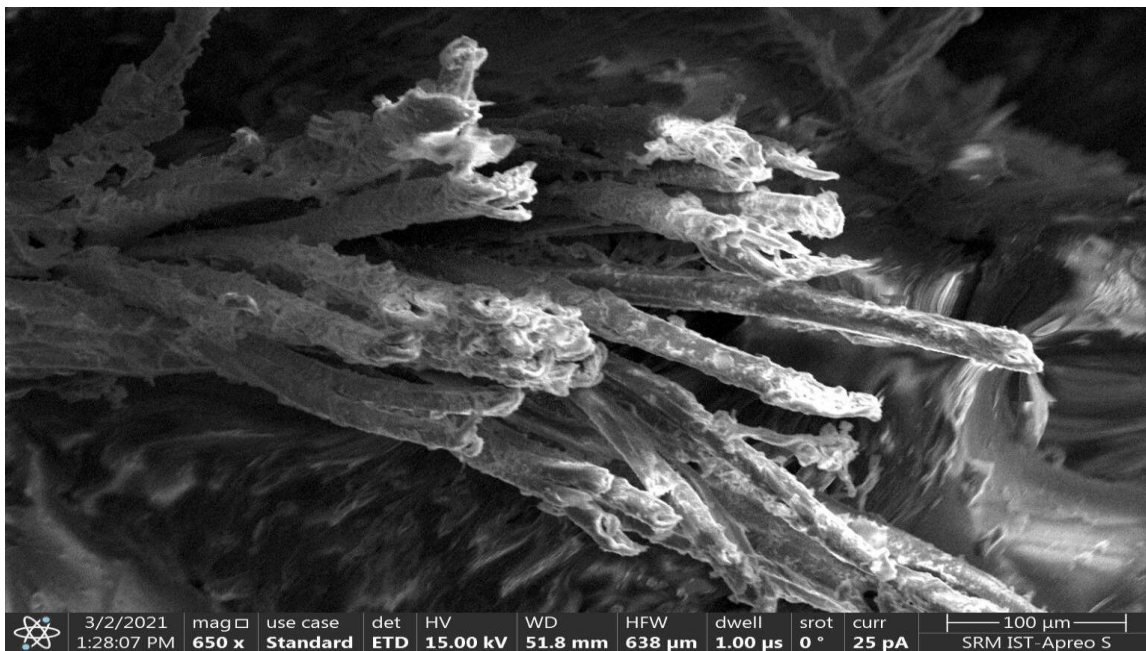


Fig 5.6: SEM image of hybrid composite material at 650x magnification with working distance of 51.8mm

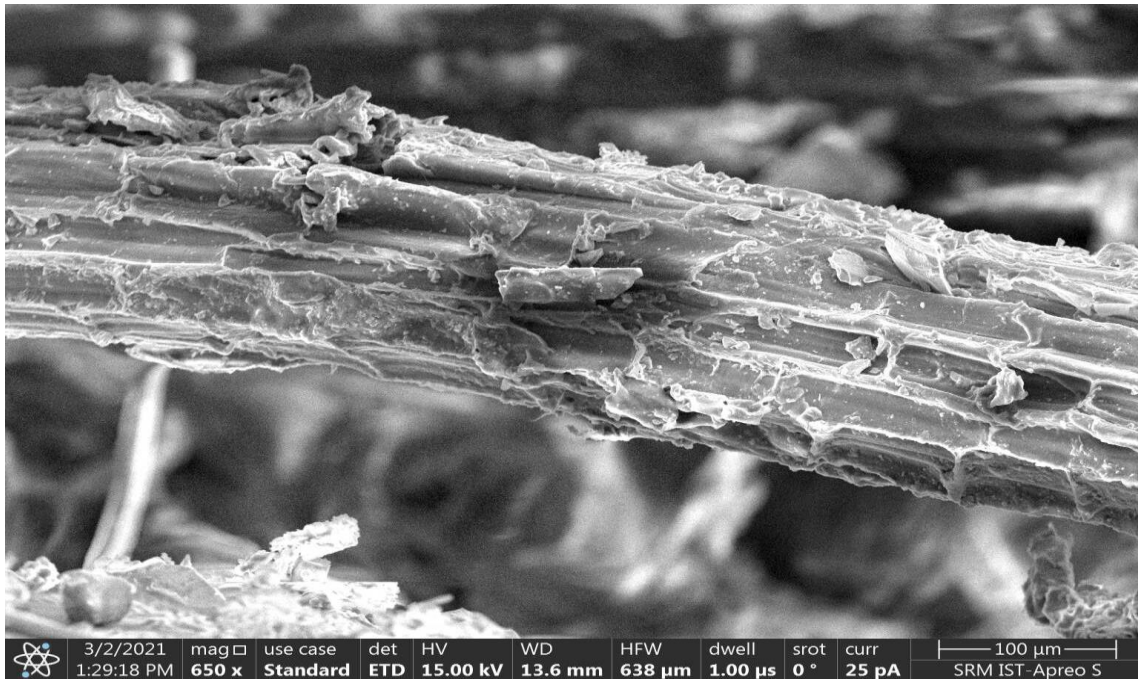


Fig 5.7: SEM image of hybrid composite material at 650x magnification with working distance of 13.6mm

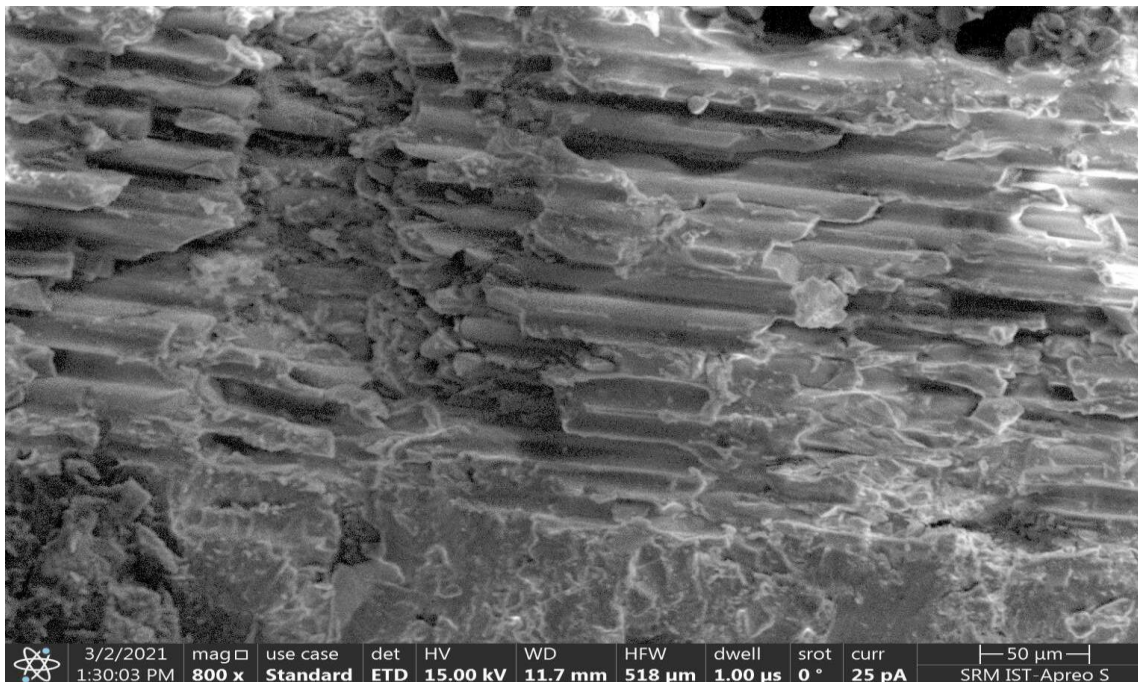


Fig 5.8: SEM image of hybrid composite material at 800x magnification

5.2.2 Energy dispersive x-ray analysis of hybrid composite material

Energy dispersive X-ray analysis, or EDS analysis, is also known as energy dispersive X-ray microanalysis. It is an analytical technique for evaluating the elements found in a sample and determining the chemical composition of the sample. It is based on the cooperation of an X-ray source and a specimen sample. EDX, EDS, and EDAX are all acronyms for Energy Dispersive X-Ray Analysis. Its uses include materials and product testing, as well as investigation and more.

The imaging power of the magnifying lens recognizes the specimen of interest in EDX systems, which are devices connected to Scanning Electron Microscope (SEM) or Transmission Electron Microscope (TEM) instruments. EDX analysis produces spectra of peaks corresponding to the elements that make up the genuine composition of the specimen sample being studied. In EDX, image processing and elemental mapping are also possible. EDX, particularly in industrial forensic science investigations and pollution investigations, proves to be exceptionally amazing when used in a multi-procedure approach. The method can be quantitative, semi-quantitative and qualitative and furthermore give spatial distribution of elements through mapping.

Figure 5.9 and Table 5.2 give the results of EDS analysis for the cracked surface of a palm fibre and s-glass particle after mechanical testing. It can be shown that carbon is the most abundant element in the study, while magnesium is also present. It contains a lot of carbon, which is contained in palm fibre. Heatshields, load plates, furnace fixtures and heating elements, and X-beam goals are all examples of carbon composite materials in use. Carbon composites are used to create rocket nozzles, which can withstand high temperatures and corrosive conditions. Apart from carbon, some different elements are accessible in the s-glass. As a result of S-Glass it has a composition of SiO_2 65wt%, Al_2O_3 25wt%, MgO 10wt%.

Full scale counts: 3145
Integral Counts: 43155

Base(16)

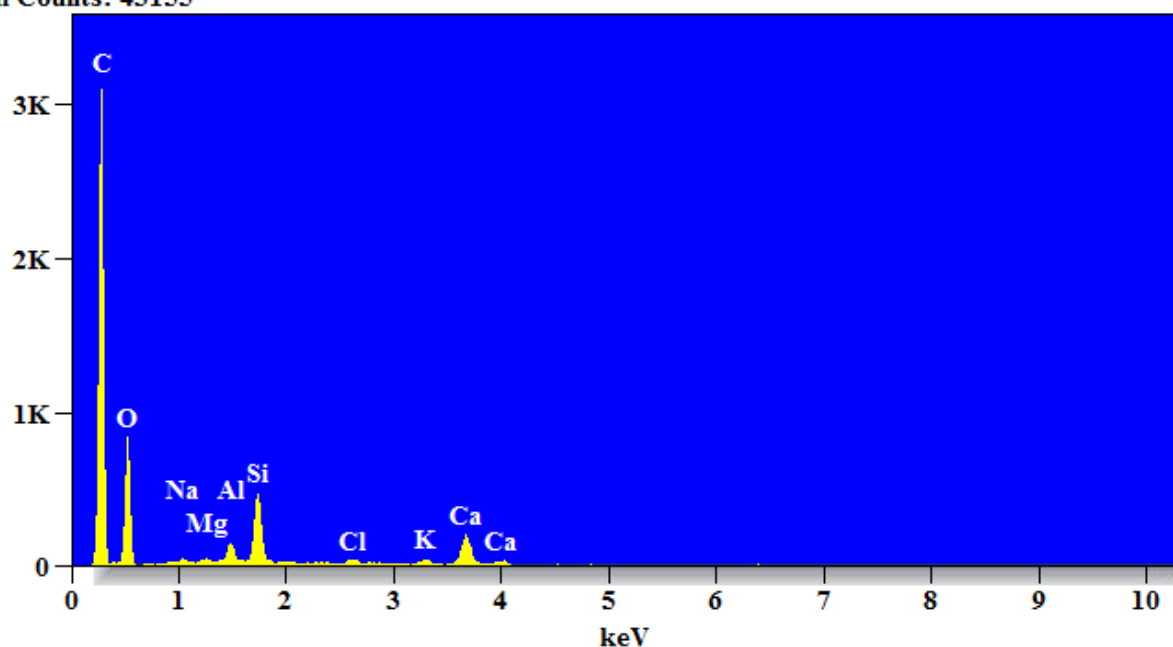


Fig 5.9: Elemental analysis of hybrid composite material in energy dispersive x-ray analysis

Table 5.2: Elemental analysis of hybrid composite material using SEM-EDX

Element	Weight %
C	49.64
O	40.11
Na	0.41
Mg	0.29
Al	1.19
Si	4.21
Cl	0.30
K	0.47
Ca	3.38
Total	100.00

CHAPTER – 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

In this project is, Mechanical properties and Morphological study of palm fibre and s-glass reinforced in the polymer matrix is investigated.

Hybrid composite materials are new materials reinforced with glass fibres. These materials have a big potential for applications in the aerospace industry. Palm fibre is a natural fibre and s-glass fibre is a synthetic fibre. The combination of natural and synthetic fibres gives eco-friendly composites with low cost.

The fabrication is done by using hand lay-up method. Epoxy resin and hardener mixer is used for fabrication process which are mixed in the ratio of 10:1. Palm fibre and s-glass are reinforced in the sandwich construction.

After curing, the fabricated plate is cut using waterjet cutting to ASTM specifications. The specimens are put through their paces, and the properties of hybrid composites are studied. A morphological analysis of the structural and elemental properties of a hybrid composite material was also carried out.

In this study, Palm fibre and s-glass reinforced in the polymer matrix and its Mechanical properties and Morphological study are investigated.

It shows the all hybrid composite material are good alternative material for aerospace industries, building construction, packing industries and automotive. As a result, hybrid composites can be used in automotive, aerospace, and marine applications for high strength, stiffness, and bending, as well as lightweight applications.

6.2 CONCLUSION

The mechanical properties and morphological analysis of palm fibre and s-glass reinforced in polymer matrix were investigated, yielding the following result,

- I. Hand lay-up method was used to create the Palm fibre and s-glass reinforced in the polymer matrix composite.
- II. After curing, the fabricated plate is cut as per ASTM standards by using waterjet cutting.
- III. Mechanical Properties, Tensile strength, Flexural strength, Impact strength and hardness were measured.
- IV. The tensile test conducted in Universal testing machine gives result of 50.92MPa on the specimen 1 (30 wt% of palm fibre). Compared to specimen 2 (20 wt% of palm fibre) and specimen 3 (10 wt% of palm fibre), the specimen 1 has a highest tensile strength which shows the hybrid composite having high tensile properties while load is applied.
- V. The flexural strength of palm fibre and s-glass reinforced in the polymer matrix composites is enhanced to $1292 \times 10^3 \text{ N/m}^2$ at specimen 2. The test is conducted on flexural strength testing machine. Fibres can be evenly distributed in the surface region of the resin in this hybrid composite material, significantly improving flexural strength.
- VI. The maximum impact test is obtained for palm fibre and s-glass reinforced in the polymer matrix composites is 0.0145 J/mm^2 for specimen 1 and lower impact value is 0.0141 J/mm^2 for specimen 3. The test is conducted in Izod impact testing machine. Specimen 1 absorbs more energy when the sudden load is applied.

- VII. The Hardness of palm fibre and s-glass reinforced in the polymer matrix composites is identified to 71.90 shore D hardness at specimen 1. This test is conducted on portable dynamic hardness tester. In structural applications, this hybrid composite offers resistance to bending, scratching, cutting, and abrasion.
- VIII. The Morphological study is carried out by using Scanning Electron Microscope. SEM results shows how the perfect bonding between the palm fibre and s-glass and fractures between the fibres at different magnifications.
- IX. In addition to the SEM analysis Energy Dispersive X-Ray analysis is carried out to analyze the elements presents in the palm fibre and s-glass reinforced in the polymer matrix. The high Carbon content of 49.64% is found and it has been known that Carbon has a high strength and it has been used for many structural applications.
- X. It shows the all hybrid composite materials are good alternative material for aerospace industries, building construction and automotive industries.

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