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EXPERIMENTALINVESTIGATIONOFHYBRID COMPOSITE LAMINATE

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Abstract— **This study presents an experimental investigation into the properties and performance of a hybrid composite laminate. The laminate is composed of multiple layers of different composite materials, strategically combined toleverage the unique properties of each material. The primary objectives of the study were to analyze the mechanicalproperties, such as tensile strength, flexural strength, hardness strength and impact resistance, of the hybrid laminate and to assess its suitability for various engineering applications. The experimental methodology involved the design and fabricationof the hybrid composite laminate using a combination of teak wood powder, jute fiber and glass fiber reinforced polymer (GFRP) materials. The laminate specimens were subjected to a series of mechanical tests, including tensile testing, flexural testing, hardness and impacttest. The hybrid laminateexhibited improved tensile strength, enhanced flexural properties, and increased impact resistance compared to monolithic composites. The study also investigated the influence of varying layer configurations and stacking sequences on the mechanical behavior of the hybrid laminate. The findings from this study contribute to the understanding of hybrid composite materials and their potential applications in aerospace, automotive, marine, and structural engineering. The optimized hybridcomposite laminate offers abalance of strength, stiffness, and durability, making it a promising candidate for lightweight and high-performance structural components in diverse engineering fields.**

Keywords—**Hybrid composite laminate, Teak wood fiber,Jute fiber, Glass fiber, Mechanical properties, Tensile strength, Flexural strength, Impact resistance, Engineering applications.**

I. INTRODUCTION

Composite materials have gained significant attention in engineering and manufacturing industries due to their exceptional mechanical properties and versatility in various applications. One area of interest within the realm of compositesisthedevelopmentandcharacterizationofhybrid composite laminates. These laminates are engineered by combining different types of composite materials in specific configurations to achieve enhanced performance characteristics that surpass those of individual constituent materials.

In this study, we will delve into the design and fabrication processes involved in creating the hybrid composite laminate, considering factors such as layer stacking sequences, resin matrices, and reinforcement orientations. Subsequently, a comprehensive series of mechanicaltests,includingtensiletesting,flexuraltesting, and impact testing, will be conducted to assess the laminate's structural integrity and performance under varying loading conditions.

II. MATERIALS

A. Teakwoodpowder

Fig.1Teakwoodpowder

The teak is very good resistance to humidity and attack by fungi and insects.It is even possible to leave it outdoors without treatment thanks to its natural oils. Teakhas a high degree of natural durability, is moderately hardand heavy with low stiffness and shock resistance but an excellent decay resistance and dimensional stability with a good acid resistance.Works reasonably well with hand or machine tools but silica in wood is tough on cutting edges and machine dust can be an irritant. Good turning andcarving properties. Gluing best done on freshly cut surfaces due to oily nature.

B. Epoxyresin

Fig.2Epoxyresin

An epoxy is a thermosetting polymer that curesupon mixing with a catalyst. It is by far the most extensively used polymer matrix for structural composites. This is owing to the strong adhesiveness of epoxy, in addition to the long history of its use in composites. Epoxy offers an outstanding combinationofmechanicalpropertiesandiscorrosion

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resistant,isdimensionallystable,exhibitsgoodadhesion,and is fairly economical. This mobility helps the resin to rapidly spread on the surface of carbon fibre. Epoxy resins traditionally made by reacting epichlorohydrin with bis-phenol A, which are linear polymers that cross-link, forming thermosetting resins basically by the reaction with the hardener. This curing method is a reaction that involves polymerization and cross-linking.

C. Hardener

Fig.3Hardener

A hardener is a component of certain types of mixtures. In some mixtures a hardener is used simply to increase the resilience of the mixture once it sets. In other mixtures a hardener is used as a curing component. A hardener can be either a reactant ora catalyst in the chemical reaction that occurs during the mixing process. A hardener may also be known as an accelerator. The hardener is shown in Fig 3. An extensive range of curing agent for epoxy resins are available depending on the process and properties required. Hardeners are almost always necessary to make an epoxy resin useful for its intended purpose. The correct type ofhardenermustbeselectedtoensuretheepoxymixturewill meet the requirements of the application.

D. Jutefiber

Fig.4Jutefiber

Jutefiber isarichand diversenaturalbiodegradable fiber that comes second in the world in terms of cellulosic fiber output. Jute fiber is widely produced in the tropical climate, and has a low environmental impact due to its biodegradable qualities. Jute is made up of 45–71.5% cellulose, 13.6–21% hemicelluloses, 12–26% lignin, 1.5% water-solublecomponent,and0.3–1%fatandwax.Jutefiber ismade up ofmicroscopic celluloseunitsthat are surrounded by lignin and hemicellulose and kept together by them. Mechanical support is provided by lignin, which contains manyaromaticrings.Anymaterialbesidescellulosethat hampers the smoothness, pliability, and fineness of jute is designated as gum. The hydrophilic nature of jute fiber and the mechanical characteristics of jute fiber reinforced polymer composites can be improved by chemical treatment. Jute fibers are also environmentally beneficial and don't createany deleteriouseffects duetothe biodegradableeffect.

E. Glassfibermat

Fig.5Glassfibermat

Glass fibers have stimulated tremendous interest as reinforcement for polymer matrices due to very low cost,high mechanical property, good heat resistance, etc. To improve the mechanical and multifunctional characteristicsof the composites, several GF reinforcements such as long longitudinal, woven mat, chopped fiber (distinct), and choppedmathavebeendeveloped.Theinterfacebetweenthe GFs and the polymer in GFs/polymer composites is criticalin influencing some of the mechanical characteristics. However, because of poor wettability, adsorption, and low electric and thermal conductivity, the inter-facial adhesion between GFs and polymers is often weak. Thereinforcements are surrounded and supported by the matrix material, which keeps their relative locations and protects them from damage and chemical assault.

III. METHODOLOGY

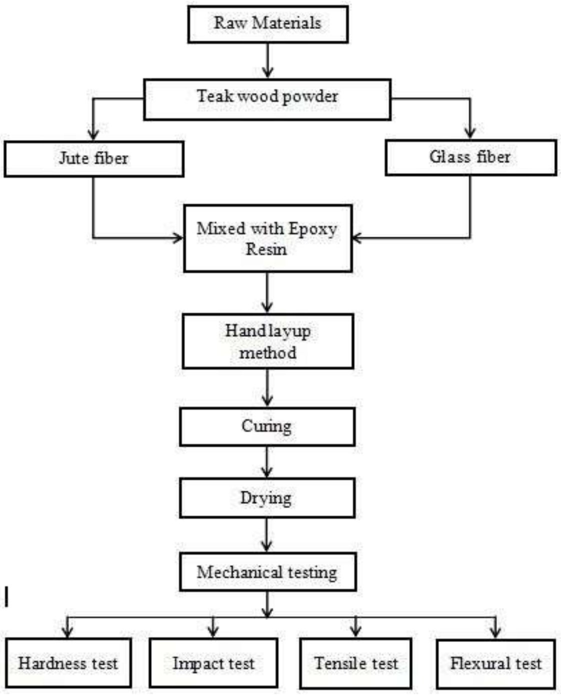

Fig.6Methodologyflowchart

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IV. FABRICATIONPROCESS

Step1:ProcurementofRaw Materials

The raw materials including the teak wood powder, glass fiber mat, jute fiber mat, epoxy resins (Ly-556) and hardeners (Hy-951) were bought from retailers.

Step2:Mineraltreatmentforjutefiber mat

Jute fiber mat is cut by specific dimensions of 300mm x 300mm and soaked in the mineral water for 3hours for getting anti shrinkage.

Step3:Preparationof-HandLay-upMethod

Two plain 500mm x 500mm tiles were wrapped by aluminium foil (11 micron). Water is sprayed to attach the aluminium foil on the tiles without air gap. Coconut oil is appliedonthewrappedaluminiumtileforremovingpurpose. Jute fiber mat and glass fiber mat are layered by following method : JGJGJ.

Fig.7Handlayupmethod

Step4:Curing

The Laminate is then kept for curing at room temperature. Curing is the process that refers to tougheningor hardening of polymer materials by cross-linking of polymer chains. The mould is kept for curing for at least 1 day. The anvil is put on the laminate for proper thickness.

Step5:Drying

Aftercuring,themouldiskeptfordryingfor1day.

Fig.8After drying

V. SPECIFICATION

TABLEISPECIFI CATION

Materials	Measurement
Jutefiber	300mmx300mm
Glassfiber	300mmx300mm
Epoxyresin	600g
Hardener	60 g
Teakwoodfiber	3 g

TABLE I represents the details ofcomposition for layering the glass mat and jute mat by adding teak wood powder in the epoxy resin and hardener.

VI. EXPERIMENTATION

A. *Tensiletesting*

ASTMD3039-Standard Test Method for Tensile Propertiesof Polymer Matrix Composite Materials

The purpose of this test method is to determine the tensile properties of polymer matrix composite materials. These materials typically consist of fibers (such as glass, carbon, or aramid fibers) embedded in a polymer matrix(such as epoxy resin). ASTM D3039 requires a testing machine capable of applying a controlled tensile load to the specimen. The test setup typically includes grips or fixturesto securely hold the specimen without causing premature failureat the grips.The dimensionsofthe specimen arewidth 25mm, and length 250mm.

B. *Flexuraltest*

ASTM D790 Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.

The purpose of ASTM D790 is to evaluate the flexural strength and modulus of elasticity of plastics and electricalinsulatingmaterials.Flexuraltesting isessentialfor assessing a material's ability to withstand bending or deflection without fracturing. ASTM D790 requires a testing machine capableof applying a bending loadto the specimen. The machine typically consists of a support span, loading nose, and a device for applying the load at a constant rate. The machine's capacity should match the expected loads based on the material being tested. The dimensions of the specimen are width 12.7mm, length 127mm. and 3.2mm thick.

C. *Impacttest*

ASTM D256 Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics

The purpose of ASTM D256 is to determine the impact resistance of plastics by measuring the energy absorbed during a standardized impact test. This test helps evaluate a material's toughness and its ability to withstand sudden impacts without fracturing. ASTM D256 requires a pendulum-type impact testing machine capable of delivering controlled impacts to the test specimen. The machinetypically consists of a swinging pendulum, a striking edge, and a device for measuring the energy absorbed by the specimen upon impact. ASTM D256 reports the impact energyin units ofjoules (J)requiredto fracturethe specimen. This energy value is used to assess the material's impact resistance, with higher energy absorption indicating greater toughness.The dimensions of the specimen are width12.7mm, length 63.5mm. and 2.5mm thick.

D. *Hardnesstest*

ASTM E384 Standard Test Method for Micro-indentation Hardness of Materials

This method is commonly used to measure the hardness of small-scale features or components, making it suitableforassessingthehardnessofmaterialslike

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composites, metals, ceramics, and polymers at a micro-scale level.ASTME384isdesignedtodeterminethemicro-indentation hardness of materials using the Vickers hardness testmethod.Itprovidesaquantitative measureofamaterial's resistance to plastic deformation under a controlled micro-indentationload.Micro-indentationhardnesstestingprovides valuable information about a material's mechanicalproperties at a micro scale level. It can be used to assess hardness gradients, hardness mapping, hardness across interfaces, and hardness of individual phases in composite materials.

VII. RESULTAND DISCUSSION

A. *Tensiletestresults*

TABLEIITENSILE TESTRESULT

Specimen	Load (KN)	Stress(MPa)
1.	6.703	49.0
2.	8.134	59.5
3.	6.964	52.6

Fig8Specimenbeforetensile testing

Fig9Specimenaftertensile testing

B. *Flexuraltestresults*

TABLEIIIFLEXURAL TESTRESULT

Specimen	Load (KN)	Stress(MPa)
1.	217.085	93.9
2.	228.405	101.5
3.	234.027	105.8

Fig10Specimenbeforeflexuraltesting

Fig11Specimenafterflexuraltesting

C. *Impacttestresults*

TABLEIV

IMPACTTESTRESULT

Specimen	Impactstrength(J)
1.	9
2.	6
3.	9

Fig12Specimenbeforeimpacttesting

Fig13Specimenafterimpacttesting

D. *Hardnesstestresults*

TABLEV

HARDNESSTESTRESULT-SHOREDHARDNESS

Specimen	Hardnessvalue
1.	38,40,42
2.	42,44,42
3.	44,45,46

Fig14Specimenbeforehardnesstesting

Fig15Specimenafterhardnesstesting

The above results are concluded by using ASTM standards. Evaluate the overall performance of the hybrid composite based on the test results and comparisons with industry standards or similar materials.

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VIII. CONCLUSION

Compare the properties and performance of the hybrid composite with those of conventional materials commonly used in similar applications. Highlight any advantagesorimprovementsofferedbythehybridcomposite over traditional materials, such as enhanced strength-to-weight ratio, reduced cost, or improved environmental resistance. Provide recommendations for optimizing the hybrid composite material, improving specific properties, or enhancing manufacturing processes based on the test results and conclusions drawn. Identify areas for further research or development to address any limitations or unanswered questions regarding the hybrid composite's performance and behavior.

These hybrid composites may be used when cost reduction is an important factor and they are alternatives for the conventional and relatively expensive materials. This composite material may be used in automotive application like car doors and agricultural applications for corrosion free and rust free. Much more research can be done usingdifferent combinations to increase the strength and hardness of the materials.

Summarize the main conclusions drawn from the study, emphasizing the significance of the findings and their implications for the hybrid composite material's real-world applications. Conclude with a final statement that reinforces the key takeaways from the report and highlights the importance of ongoing research and development in hybrid composite materials.

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