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EXPERIMENTAL INVESTIGATION OF NATURAL FIBRE REINFORCED POLYMER COMPOSITE

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Abstract - Fiber-reinforced polymer composites have a high specific strength and modulus,It have dominated a variety of applications for a long time. Natural or synthetic fibers can be used as reinforcement in reinforced plastics. Only glass, carbon, and other synthetic fibers, according to previous research, have been used in plastics with fiber reinforcement. Despite having a high specific strength and a high cost of production, glass and other synthetic fiber-reinforced plastics have very limited applications. In this regard, a study has been conducted to make use of coir, a natural fiber that can be found in abundance in India. Natural fibers are not only lightweight and durable, but they are also relatively inexpensive. A new set of natural fiber-based polymer composites using epoxy resin as a reinforcement and coconut coir is the subject of this study's development and characterization. The mechanical properties of the newly developed composites are what set them apart. The effect of fiber length on the mechanical behavior of these epoxy-based polymer composites is the subject of experiments. Coir composites are created and their mechanical properties are evaluated in this work. Filtering electron micrographs acquired from cracked surfaces were utilized for a subjective assessment of the interfacial properties of coir/epoxy. Based on these findings, coir may have potential as a reinforcing material for a variety of structural and non-structural applications. The effects of fiber content, fiber orientation, loading pattern, and fiber treatment on the mechanical behavior of coconut coir-based polymer composites could be investigated further in this work

***Key Words*:** Fiber-reinforced polymer composites, . Natural or synthetic fibers, epoxy resin, mechanical properties.

1.INTRODUCTION

Composites, and plastics have recently replaced the majority of design materials. Composite materials have found new uses and have seen rapid expansion into new market segments. The current challenge is to make composites strong enough to replace other materials and cost-effective enough to replace them, despite the fact that they have actively demonstrated their value as materials that save weight. Modern composite materials include a wide range of materials that are utilized in both straightforward and intricate contexts. As a direct consequence of this, numerous brand-new strategies that are currently being implemented within the company have seen improvements.The composites industry has begun to recognize the numerous industrial applications, primarily in the transportation sector. Composites' usage and volume have steadily increased due to recent advancements in polymer gum network materials and high-performance glass, carbon, and aramid filaments. As a direct result of this increase, the price has clearly decreased. FRP with superior execution can be found in a wide variety of applications, such as composite armoring plans for blast protection, wind factory edges, modern shafts, and fuel chambers for gaseous petrol vehicles, paper-making rollers, and even contributing to emission reductions. Finishing made of composite materials are also used to repair damage caused by seismic movement or make existing structures safer from earthquakes.In this current work, chemically treated coir fibre is used to reinforce polypropylene matrix to form a biocomposite material and fabricate value added products by injection moulding. The chemical treatment of coir fibre leads to minimize the hydrophilic characteristics and diminish the water absorption property of the composite.

1.2 CLASSIFICATION OF COMPOSITES

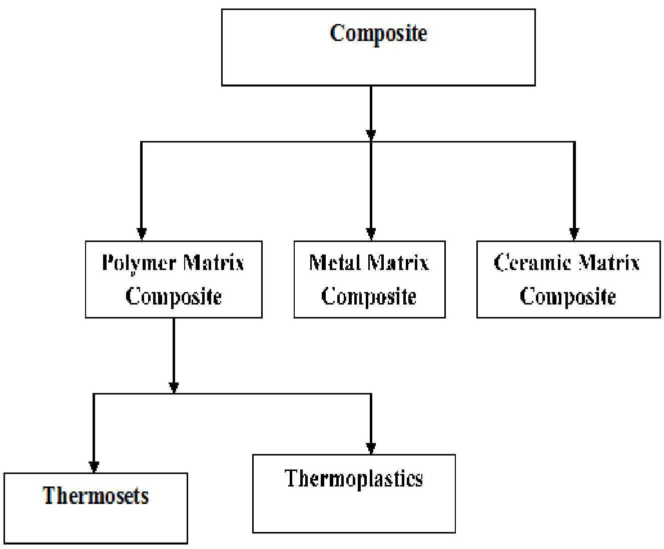

Fig -1: Classification of Composites

1.3 FIBER

Fiber or fiber is a characteristic or fake substance that is essentially longer than it is wide. Strands are in many cases utilized in the production of different materials. The most grounded designing materials frequently consolidate strands, for instance carbon fiber and super high-atomic weight polyethylene.

1.3.1 CLASSIFICATION OF FIBERS

In general, fibers are classified into two types.

1. Man-made fibers
2. Natural fibers

1.3.1.1 MAN-MADE FIBERS

Natural raw materials or synthetic chemicals can be used to make synthetic fibers. Natural cellulose is used to make many different kinds of fiber, including rayon; modal and Lyocell, which was developed more recently. There are two types of fibers based on cellulose: modified cellulose, such as cellulose acetates, and regenerated or pure cellulose, such as from the cuproammonium process.

Examples

1. Glass fibers
2. Carbon fibers
3. Kevlar 49 fibers
4. Boron fibers
5. Ceramic fibers

1.3.1.2 NATURAL FIBERS

The fibers that come from or are produced by animals and plants are referred to as "natural fiber." The production of composite materials makes extensive use of these fibers. By mattifying various layers of natural fibers into sheets, paper and felt a type of textile material can be prepared.The majority of natural fibers are known to be effective liquid and sweat absorbers. Natural fibers can be used to create a wide range of textures either by themselves or in combination with two or more other natural fibers. For instance, cotton fabrics, which are distinguished by their relatively light weight and supple texture thanks to the use of cotton fibers, which are natural fibers derived from the cotton plant. The fact that cotton fiber can be woven into clothing in a variety of sizes and colors is another advantage. People who live in hot and humid areas typically prefer to wear clothing made of natural fibers like cotton over clothes made of synthetic fibers.

1.4 NEED FOR NATURAL FIBERS

The advantages of natural fibers include their low cost, lightweight, renewability, biodegradability, and high specific properties. Natural fibers are sustainable materials that are readily available in nature. Natural fiber-based composite materials' sustainability has increased their use in a variety of manufacturing fields. We have discussed the various natural fiber sources, their properties, modifications to natural fibers, the effects of treatments on natural fibers, and other topics in this paper. In addition, we provide a synopsis of the primary uses for natural fibers as well as their efficient application as reinforcement for polymer composite materials.

1.5 MATRIX

The role of matrix in a fibre reinforced composites are.to protect against a hostile environment with a barrier. The matrix has little effect on a composite structure's ability to carry tensile loads and protect the fibers from mechanical abrasion. However, the inter-laminar shear and plane shear properties of the composite materials are significantly influenced by the matrix chosen. The matrix provides lateral support against the possibility of fiber buckling under compression loading, thereby influencing to some extent the compressive strength of the composite materials. Under bending loads, the inter-laminar shear strength is an important design consideration for the structure, whereas under torsion loads, the plane-shear strength is important. In the creation of structures that can withstand damage, the interaction between the matrix and the fibers is also crucial.

1.5.1 TYPES OF MATRIX

The various types of matrices are as follows:

1. Polymeric Matrix
   - Thermo plastic polymers
   - Thermoset polymers
2. Ceramic Matrix
3. Metal Matrix

2. MATERIALS AND METHODOLOGY

The mechanics of composite materials manages stresses, strains and distortions at the point when they are exposed to mechanical burdens and warm conditions A typical suspicion in the mechanics of regular materials like prepares and aluminum is that they are homogeneous and isotropic. Unless extremely cold worked, the properties of a homogeneous material will be uniform throughout. On the other hand, the fiber-reinforced composites (FRC) are non homogeneous and isotropic (orthotropic). Consequently, FRC's mechanics are significantly more complicated than those of conventional materials. There are two levels of research into the mechanics of FRC materials.

2.1 HYBRID COMPOSITES

When low cost, easy fabrication, and a high strength-to-weight ratio are required, hybrid composite materials are used extensively in engineering. The combination of tensile modulus, compressive strength, and impact strength that cannot be achieved in composite materials is provided by hybrid composites. Hybrid composites are rapidly gaining popularity as highly efficient and high-performance structural materials in recent years. Typically, hybrid composites are utilized when both longitudinal and lateral mechanical performances are required or when a combination of properties from various fiber types must be achieved. According to reports, the researchers have long held a keen interest in the investigation of novel applications of hybrid composites. Both the number of uses for fiber-reinforced plastics and the variety of fiber/resin systems that designers can choose from are on the rise at the same time. However, limitations like high cost and brittle fracture behavior are only relevant in highly specialized applications where qualities like low density, high rigidity, and high strength take precedence. It may be possible to create a material with the combined advantages of the individual components and simultaneously mitigating their less desirable qualities by mixing two or more types of fiber in a resin to form a hybrid composite. Additionally, the properties of these materials ought to be adaptable to meet specific requirements. There are numerous circumstances in which, for instance, a material with a high modulus is required, but the catastrophic brittle failure that is typically associated with such a material is unacceptable. A strut member's initial modulus should be high, the material should have limited yielding, and the load carrying capacity should be reduced as little as possible. There are two distinct approaches to the production of hybrid fiber-reinforced materials: either intimately mingling the fibers in a single matrix or laminating alternate layers of each type of composite. In this work the last procedure has been utilized and the accompanying contemplations apply to this kind of crossover material. A hybrid system can theoretically incorporate a number of distinct fiber types.

2.2 EPOXY RESIN & HARDENER

Polymer resin is a transparent, liquid plastic that hardens into a thick,long-lasting, glossy coating. It is resistant to water and fade when hardened. This kind of resin is often used to seal finishes and create a long-lasting, glass-like surface on furniture. It can also be used in many other crafts when the artist wants a thick, glossy finish.A polymer resin consists of two components: a liquid catalyst and a liquid plastic resin. The catalyst activates the liquid resin, which initiates the hardening process. The user mixes the two components until they are completely combined, typically in equal amounts. Due to the chemical reaction between the resin and the catalyst, it is normal for the resin to heat up during the mixing process.

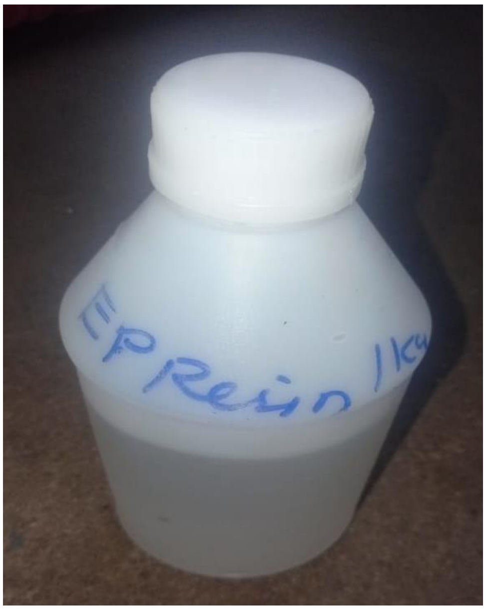

Fig -2: Epoxy Resin

The resin is self-leveling when it is still liquid, which means that as it hardens, it flows and forms a level surface. The resin begins to harden or cure after being poured.

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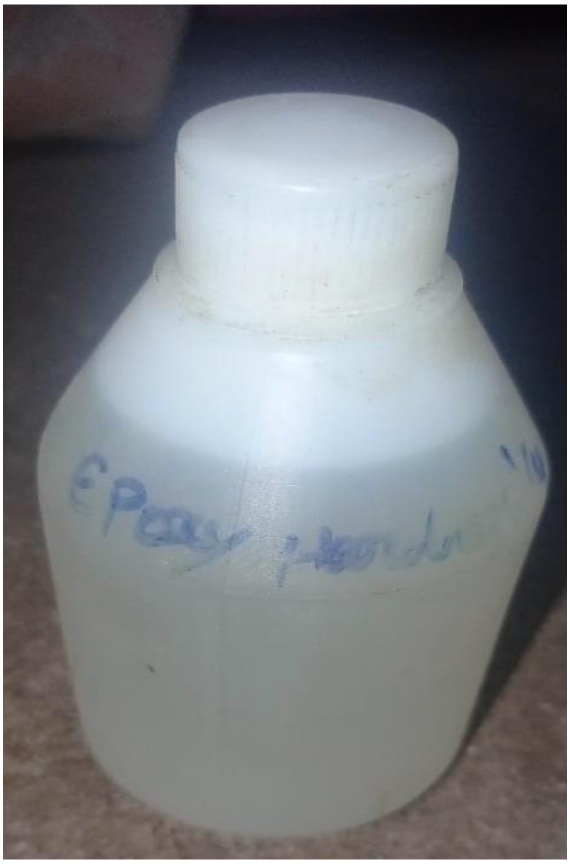

Fig -3: Epoxy Hardner

The chemical reaction that causes the resin to transform from a liquid to a solid is known as "curing." Bubbles may form while it is curing, but they can be removed with heat. A hot breath can bring the bubbles to the surface, where they will naturally pop, for smaller projects. Run a blowtorch lightly over the top of the resin to heat it enough to cause bubbles to rise on larger surfaces.

2.3 TREATMENT OF FIBER

Fibers as received are washed with distilled water to remove the surface dirtpresent in the fibers and then the fibers are dried in air circulating oven at a temp of 1000c until it gains a constant weight .Then the fibers are designated as washed fibers. For de-waxing the coir fibers are cooked in a mixture of ethanol and benzene in a ratio 1:2 by Roy[5] . We took 300ml ethanol and 600ml benzene for this process. The fibers are cooked with these chemicals for 12hrs so that to attain24 hohlraum character which means the substances lying in layers with free spaces inbetween.During this process the fibers are cooked in this solution under gradualincrease and decrease of temperature of the bath from 30-55.5c.this process of heating and cooling was done per every 2 hrs for a period 12 hrs. Finally the fiber bundles are removed from the mixture at 30c and washed with distilled water. Then the fibers are again dried in a oven at a temperature of 100c until it gets constant weight. Then the fiber is called as de-waxed coir fiber.

2.3.1 NAOH TREATMENT

The fiber was socked in 10% NaOH solution for 4 hours at 25 degreeCelsius and then washed in running distilled water. pH paper was used toascertain the removal of NaOH from treated fiber. After this the fiber wasdried in hot air. This treatment is done to remove the cellulose from thefiber outer surface so that the binding between the fiber and polymer canbe more efficient.

Fig-4: Naoh Treatment

2.3.2 WARM WATER TREATMENT

Warm water treatment of fiber is done to remove any dirt particles presentin the fiber, presence of dust particle may cause problem in matrixformation. For this the fiber was heated for 4 minutes in 60-degree Celsiuswarm water.

2.3.3 SILICA FUME

Silica fume, also known as microsilica, (CAS number 69012-64-2, EINECS number 273-761-1) is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete. It is sometimes confused with fumed silica (also known as pyrogenic silica, CAS number 112945-52-5). However, the production process, particle characteristics and fields of application of fumed silica are all different from those of silica fume.

Fig-5: Silica Fume Treatment

2.4 FABRICATION OF COMPOSITE PLATE

A handmade wooden mold is designed for the fabrication of the randomly oriented raw coir fiber-reinforced epoxy composite (RCFREC) and de-waxed fiber reinforced epoxy composite (DCFREC). First, a releasing plastic is spread over the bottom of the wooden mold. Heavy duty silicon spray is applied to the plastic sheet for easy removal of the composite plate. The fibers are cut into 20 mm length and distributed uniformly at the bottom of the mold which is prepared before. Fifteen volume percentage of the fiber is used for the fabrication of the composite. Initially, epoxy and hardener are mixed together on a weight percentage of 10:1 to form a matrix. The matrix is poured over the fibers evenly then pressed and pushed down with the iron roller to avoid and eliminate the air bubbles. Finally, load is given to it to remove excess matrix and left for curing at room temperature for 24 h.

2.5 GENERAL CHARACTERISTICS

The strength and modulus of many fiber-reinforced polymers are either comparable to or superior to those of many conventional metallic materials. The strength-to-weight and modulus-to-weight ratios of these composite materials clearly outperform those of metallic materials due to their low density. Additionally, many composite laminates have excellent fatigue strength and fatigue damage tolerance. As a result of these factors, fiber-reinforced polymers have emerged as a significant class of structured materials. Many weight-critical components in the aerospace, automotive, and other industries use them or are considering using them in place of metals. Because their properties are the same or nearly so regardless of the direction of measurement, traditional structure metals like steel and aluminum alloys are regarded as isotropic. A fiber-reinforced composite is not an isotropic material because, in general, its properties strongly depend on the direction of measurement. When these properties are measured in the longitudinal direction of the fibers, for instance, the tensile strength and modulus of a unidirectionally oriented fiber-reinforced polymer are at their highest levels. These properties are lower at any other measuring angle. When they are measured in the transverse direction of the fibers, or at a 90-degree angle to the longitudinal direction, the minimum value is observed. Other mechanical and thermal properties, such as impact strength, the coefficient of thermal expansion (CTE), and thermal conductivity, exhibit a corresponding angular dependence. A more balanced set of properties can be achieved through bi- or multidirectional reinforcement. Even though these properties are lower than those of a unidirectional composite's longitudinal properties, they still offer a significant unit weight advantage over common structural metals.

2.6 METHODS

Major constituents in a fibre-reinforced composite material are the reinforcing fibres and matrix, which act as a binder for the fibres. Other constituents that may also be found are coupling agents and coatings are applied on the fibres to improve their wetting with the matrix as well as to promote bonding across the fibre-matrix interface. Both in turn promote a better load transfer between the fibres and the matrix. Fillers are used with some polymeric matrices. Primarily to reduce cost and improve their dimensional stability. Manufacturing of a compositestructure starts with the incorporation of a large number of fibres into a thin layer of matrix to form a lamina (ply). The thickness of a lamina is usually in the range of 0.1-1mm. If continuous (long) fibres are used making the lamina they may be arranged either in unidirectional orientation (i.e., all fibres in one direction), in abidirectional orientation (i.e., fibres in two directions, usually normal to eachother), or in a multidirectional orientation (i.e., fibres in more than two directions). The bi-or multidirectional orientation of fibres is obtained by weaving or other process used in the textile industry. For a lamina containing unidirectional fibres, the composite material has the highest strength and modulus in the longitudinal direction of the fibres. However, in the transverse direction, its strength and modulus are very low. For a lamina containing bidirectional fibres, the strength and modulus can be varied using different amounts of fibres in the longitudinal and transverse directions. A lamina can also be constructed using discontinuous (short) fibres in a matrix. The discontinuous fibres can be arranged either in unidirectional orientation or in random orientation. Discontinuous fibrereinforced composites have lower strength and modulus than continuous fibre composites. However, with random orientation of fibres it is possible to obtain equal mechanical and physical properties in all directions in the plane of the lamina. The thickness required to support a given load or to maintain a given deflection in a fibre reinforced composites structure is obtained by stacking several laminas in a specified sequence and then consolidating them to form a laminate. Various laminas in a laminate may contain fibres either all in one.

3. RESULTS

3.1 TENSILE TEST

Table -1: Tensile result

Test Name : TENSILE TEST	Test Type : Normal	Test Mode : Tensile
Elongation Device : CrossHead	Test Parameter : Peak Load	Test Speed [mm/min] : 2.00

Sample No.	CS Area [mm²]	Peak Load [N]	%Elongation	UTS [N/mm²]
000001	75.000	464.033	0.690	6.190
000002	75.000	441.558	0.540	5.886
000003	75.000	567.371	0.710	7.564

Table -2: Summary report

	CS Area [mm²]	Peak Load [N]	%Elongation	UTS [N/mm²]
Min	75.000	441.558	0.540	5.886
Max	75.000	567.371	0.710	7.564
Avg	75.000	490.987	0.647	6.547
Std Dev.	0.000	67.098	0.093	0.894
Variance	0.000	4502.157	0.009	0.799
Median	75.000	464.033	0.690	6.190

3.2 COMPRESSION TEST

Table-3: Compression Test result

Test Name : COMPRESSION TEST	Test Type : Normal	Test Mode : Compression
Elongation Device : CrossHead	Test Parameter : Peak Load	Test Speed [mm/min] : 2.00

Sample No.	CS Area [mm²]	Peak Load [N]	Compressive Strength [N/mm²]
000001	75.000	837.774	11.174
000002	75.000	889.708	11.860
000003	75.000	990.261	13.204

Table-4: summary report

	CS Area [mm²]	Peak Load [N]	Compressive Strength [N/mm²]
Min	75.000	837.774	11.174
Max	75.000	990.261	13.204
Avg	75.000	905.914	12.079
Std Dev.	0.000	77.524	1.033
Variance	0.000	6010.023	1.067
Median	75.000	889.708	11.860

3.3 FLEXURAL TEST

Table-5: Flexural test result

Test Name : BENDING TEST	Test Type : Normal	Test Mode : Compression
Elongation Device : CrossHead	Test Parameter : Peak Load	Test Speed [mm/min] : 2.00

Sample No.	CS Area [mm²]	Peak Load [N]	Flexural Strength (MPa)	Flexural Modulus (GPa)
000001	39.000	45.136	28.933	2182.779
000002	39.000	58.458	37.473	47.810
000003	39.000	44.586	28.581	2209.580

Table-6: Summary report

	CS Area [mm²]	Peak Load [N]	Flexural Strength (MPa)	Flexural Modulus (GPa)
Min	39.000	44.586	28.581	47.810
Max	39.000	58.458	37.473	2209.580
Avg	39.000	49.393	31.662	1470.056
Std Dev.	0.000	7.855	5.035	1232.029
Variance	0.000	61.699	25.354	1517894.380
Median	39.000	45.136	28.933	2152.778

4. CONCLUSIONS

This review article provides a compact and informative summary of natural fiberreinforced polymer matrices from the perspective of product design development. Among the three main sources of natural fibers are plants, animals, and minerals, and these plant fibers or cellulosic fibers are in high demand, having developed since the resources they require are widely available, consume less energy, and are non-toxic to nature and humans.In general, natural fibers are made up of several main constituents, such as cellulose, hemicellulose, lignin, and pectin. Many researchers have discovered the good mechanical performance of these natural fibers due to the cellulose, which provides the good shape and49 structural integrity of the fibers. Thus, the integration of natural fibers with a polymer matrix in composites benefits various industries, as they exhibit low density, lower solidity, biodegradability, and cheapness compared to synthetic composites. Natural fiber composites are an effective way of improving the quality of products developed from them, in terms of environmental suitability, and economic and technical feasibility. The most common natural fibers used in composite products are flax, coir, hemp, and jute, while roselle, sugar palm, and kenaf are examples of emerging fibers due to their high mechanical strength and stiffness that are suitable for many engineering applications. It can be concluded that appropriate product design and manufacturing processes of NFPCs are required to enhance the properties of the products and their materials toward optimized strength and functionality. To ensure the optimization of the strength and functionality of natural fiber composite products, engineering design processes and techniques such as TRIZ, brainstorming, the voice of customers (VOCs), and morphological charts are essential. These techniques could define the problems of users and refine them in terms of the product's functionality. In the end, an appropriate manufacturing process incorporates the product's design and its applications. In the future, further research will be required to develop optimized engineering design techniques that complement the strength of the natural fiber composites, manufacturing processes, and functionality for heavy industry applications. Even now, natural fiber composites have the potential to be used in many applications that do not require very high load-bearing or high-temperature working capabilities.

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