TO DEVELOP A NEW CLASS OF NATURAL FIBER BASED POLYMER COMPOSITES TO EXPLORE THE POTENTIAL OF COIR FIBER

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ABSTRACT

Fiber-reinforced polymer composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus.The fiber which serves as a reinforcement in reinforced plastics may be synthetic or natural. Glass and other synthetic fiber-reinforced plastics possess high specific strength; their fields of application are very limited because of their inherent higher cost of production. Natural fibers are not only strong and lightweight but also relatively very cheap. The present work describes the development and characterization of a new set of natural fiber based polymer composites consisting of coconut coir as reinforcement and experiments are carried out to study the effect of fiber length on mechanical behavior of these epoxy based polymer composites epoxy resin. In the present work, coir composites are developed and their mechanical properties are evaluated. Scanning electron micrographs obtained from fractured surfaces were used for a qualitative evaluation of the interfacial properties of coir/epoxy. These results indicate that coir can be used as a potential reinforcing material for many structural and non-structural applications. This work can be further extended to study other aspects of such composites like effect of fiber content, fiber orientation, loading pattern, fiber treatment on mechanical behavior of coconut coir based polymer composites.

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INTRODUCTION

The advantage of composite materials over conventional materials stem largely from their higher specific strength, stiffness and fatigue characteristics, which enables structural design to be more versatile. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. The reinforcement may be platelets, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material. Long fibers that are oriented in the direction of loading offer the most efficient load transfer.

1.1 Composites: A definition, a composite material is made by combining two or more materials to give a unique combination of properties, one of which is made up of stiff, long fibers and the other, a binder or 'matrix' which holds the fibers in place.

1.2 Composites Properties: Composites consist of one or more discrete phases embedded in a continuous phase to produce a multiphase material which possesses superior properties that are not obtainable with any of the constituent materials acting alone. These constituents remain bonded together but retain their identity and properties. The continuous phase which is present in greater amount in composites is termed as matrix. The discrete phase is generally harder and stronger than the continuous phase and is called the „reinforcement or „reinforcing material. The geometry of the reinforced phase is one of the major parameter in determining the effectiveness of the reinforcement. Properties of composites are strongly depend on the characteristics of their constituent materials, their distribution and the interaction among them Further, the need of composite for high strength to weight ratio, corrosion resistance, lighter construction materials and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases weight but also absorbs the shock & vibrations through tailored microstructures.

1.3 Need of Composite

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications.

The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. It is essential that there be an integrated effort in design, material, process, tooling, quality assurance, manufacturing, and even program management for composites to become competitive with metals. The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years.

The increased volume has resulted in an expected reduction in costs. High performance FRP can now be found in such diverse applications as composite armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight.

Further, the need of composite for lighter construction materials and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock & vibration through tailored microstructures.

Composites are now extensively being used for rehabilitation/strengthening of pre-existing structures that have to be retrofitted to make them seismic resistant, or to repair damage caused by seismic activity. Unlike conventional materials (e.g., steel), the properties of the composite material can be designed considering the structural aspects. The design of a structural component using composites involves both material and structural design. The use of composites will be a clear choice in many instances, material selection in others will depend on factors such as working lifetime requirements, number of items to be produced (run length), complexity of product shape, possible savings in assembly costs and on the experience & skills the designer in tapping the optimum potential of composites. In some instances, best results may be achieved through the use of composites in conjunction with traditional materials.

1.4 Composites Classification Composite materials can be classified in different ways.

The two broad classes of composites are:-

(1) Particulate composites and

(2) Fibrous composites.

1.4.1 Particulate composites

A particulate composite is composed of particles suspended in a mixture. It may be spherical, cubic, tetragonal, a platelet, or other shape, but it is approximately equal. Normally, particles that are not very effective in improving fracture resistance; they increase the stiffness of the composite to a limited extent. There are two subclasses of particulates, flake and filled/skeletal. A flake composite is generally composed of flakes with large ratios of platform area to thickness, suspended in a matrix material. A filled/skeletal composite is composed of a continuous matrix filled. Particle fillers are widely used to improve the properties of matrix materials to modify the thermal and electrical conductivities, improve performance at elevated temperatures, reduce friction, increase wear and abrasion resistance, improve machinability, increase surface hardness and reduce shrinkage.

1.4.2 Fibrous composites: A fiber is defined by its length which is much greater than its cross sectional dimensions. Fibers are very effective in improving the fracture resistance of the matrix because reinforcement having a long dimension opposes the growth of cracks normal to the reinforcement that might otherwise lead to failure, particularly with brittle matrices. Fibers, because of their small cross- sectional dimensions, are not directly usable in engineering applications. They are, therefore, embedded in matrix materials to form fibrous composites. The matrix serves to bind the fibers together, transfer loads to the fibers and protect them against environmental attack and damage due to handling. Fibrous composite can be subdivided into - continuous fiber (large aspect ratio), discontinuous (short) fiber (low aspect ratio) and hybrid.

1.4.2.1 Continuous fibers: Continuous fiber composites can be either single layer or multilayered. The single layer continuous fiber composites can be either unidirectional or woven, and multilayered composites are generally referred to as laminates. The material response of a continuous fiber composite is generally orthotropic.

1.4.2.2 Discontinuous fibers: Material systems composed of discontinuous reinforcements are considered single layer composites. The discontinuities can produce a material response that is anisotropic, but in many instances the random reinforcements produce nearly isotropic composites.

1.4.2.3 Hybrid fibers: These are the combination of more than one fiber.

1.5 Types of Composites

For the sake of simplicity, however, composites can be grouped into categories based on the nature of the matrix each type possesses [7]. Methods of fabrication also vary according to physical and chemical properties of the matrices and reinforcing fibers.

(a) Métal Matrix Composites (MMC)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminium, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide.

(b) Ceramic Matrix Composites (CMCs)

Ceramic matrix composites have ceramic matrix such as alumina, calcium, alumina silicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced with silicon carbide fibers. These composites offer the same high temperature tolerance of super alloys but without such a high density. The brittle nature of ceramics makes composite fabrication difficult. Usually most CMC production procedures involve starting materials in powder form. There are four classes of ceramics matrices: glass (easy to fabricate because of low softening temperatures, include borosilicate and alumino silicates), conventional ceramics (silicon carbide, silicon nitride, aluminum oxide and zirconium oxide are fully crystalline), cement and concreted carbon components.

(c) Polymère Matrix Composites (PMCs)

The most common advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low density of the constituents the polymer composites often show excellent specific properties.

EXPERIMENTAL PROCEDURE

The raw materials used in this work are:-

1. Coconut coir fiber
2. Epoxy resin
3. Hardener

Composite Specimen Preparation

Preparation of Coconut coir fiber

Coconut coir fiber is collected and cut in to a length of 20 mm approximately. These fibers are washed in water and then dried with the help of hair drier.

Epoxy Resin and Hardener

Epoxy resins are relatively low molecular weight pre-polymers capable of being processed under a variety of conditions. Two important advantages of these over unsaturated polyester resins are: first, they can be partially cured and stored in that state, and second they exhibit low shrinkage during cure. However, the viscosity of conventional epoxy resins is higher and they are more expensive compared to polyester resins. The cured resins have high chemical, corrosion resistance, good mechanical and thermal properties, outstanding adhesion to a variety of substrates, and good and electrical properties. Approximately 45% of the total amount of epoxy resins produced is used in protective coatings while the remaining is used in structural applications such as laminates and composites, tooling, moulding, casting, construction, adhesives, etc.

The type of epoxy resin used in the present investigation is Derakane 411-350 epoxy vinyl ester resin which chemically belongs to epoxide family. Epoxy resins are characterized by the presence of a three-member ring containing two carbons and an oxygen (epoxy group or epoxide or oxirane ring). Epoxy is the first liquid reaction product of bisphenol-A with excess of epichlorohidrin and this resin is known as Diglycidyl-Ether of Bisphenol-A (DGEBA). DGEBA is used extensively in industry due to its high fluidity, processing ease, and good physical properties of the cured of resin. Both the epoxy and hardener were supplied by Ashland Polymers, USA.

Preparation of composite laminates

Two wooden molds of dimension (150x150x3.5) mm and (130x80x3) mm was used for casting the composite sheet. First mold size is used for preparing the samples for tensile strength and second mold size is used to prepare the samples for flexural testing. The first group of samples was manufactured with 5, 10, 20, 25 and 30 % volume fraction of fibers**.** Usual hand lay-up technique was used for preparation of the samples. For different volume fraction of fibers, a calculated amount of epoxy resin and hardener (ratio of 10:1 by weight) was thoroughly mixed in a glass jar and placed in a vacuum chamber to remove air bubbles that got introduced. This procedure was performed for 10 minutes initially. The mixture was re-stirred and the vacuum procedure was performed again for 10 minutes for further removal of bubbles. Figure 3.1 illustrates the mold used to construct the composite. For quick and easy removal of composite sheets, mold release sheet was put over the glass plate and a mold release spray was applied at the inner surface of the mold. After keeping the mold on a glass sheet a thin layer (1mm mm thickness) of the mixture was poured. Then the required amount of fibers was distributed on the mixture. The remainder of the mixture was then poured into the mold. Care was taken to avoid formation of air bubbles. Pressure was then applied from the top and the mold was allowed to cure at room temperature for 72 hrs. During application of pressure some amount of mixture of epoxy and hardener squeezes out. Care has been taken to consider this loss during manufacturing of composite sheets. After 72 hrs the samples were taken out of the mold. Figure 3.2 shows the photograph of the composite and some of the specimen cut for further experimentation. After cutting they were kept in airtight container. The samples for tensile test, flexural test, SEM and hardness test are prepared in the following volume fractions.

Volume fractions of different samples

S.No Composites Composition

1. EBSF-1 Epoxy + Coconut coir fibre (0% Volume Fraction)
2. EBSF-2 Epoxy + Coconut coir fibre (5% Volume Fraction)
3. EBSF-3 Epoxy + Coconut coir fibre (10% Volume Fraction)
4. EBSF-4 Epoxy + Coconut coir fibre (20% Volume Fraction)
5. EBSF-5 Epoxy + Coconut coir fibre (25% Volume Fraction)
6. EBSF-6 Epoxy + Coconut coir fibre (30% Volume Fraction)

Figure 1: Mold Preparation for preparing the sample

Figure 2: Samples prepared for tensile test

Figure 3: Samples prepared for flexural testing

CHARACTERIZATION OF MECHANICAL PROPERTIES

Tensile and flexural tests were carried out on INSTRON 3382,100 kN Universal Testing Machine at a temperature of 23±2˚C, and with relative humidity of 50±5%. Testing procedures were carried out in ASTM D638 for tensile tests and ASTM D790 for flexural tests. Summary of the entire test performed are shown in the Table 1

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Testing	**Machine Used**	**Working Variables**	**No of Specimen**	**Standard Used**
Tensile	INSTRON 3382 UTM	Load cell : 100 KN Rate : 5 mm/min	6×5=30	ASTM D638
Flexural	INSTRON 3382 UTM	Load cell : 100 KN Rate : 1.32 mm/min	6×5=30	ASTM D790

Table 3.2: Summary of tests

RESULT

Table: Mechanical properties with varying % of coconut coir fiber

S.No	**Fiber Content (%)**	**Orientation (deg)**	**Tensile Strength (MPa)**	**Flexural Strength (MPa)**	**Hardness (HRL)**
1	**-**	Random	18.61	19.03	**46**
2	**5**	Random	24.56	23.84	**52**
3	**10**	Random	29.03	31.54	**59**
4	**20**	Random	37.32	41.32	**67**
5	**25**	Random	43.02	49.81	**79**
6	**30**	Random	38.67	43.73	**82**

CONCLUSION

The results of the work shows that a useful composite with good properties could be successfully developed using coconut coir fiber as reinforcing agent for the polymers matrix. From this, several conclusions can be drawn regarding to mechanical properties of composite (tensile, flexural and micro hardness) to the effect of content of the fiber.

As the fiber content in unsaturated polymer increased in term of volume %, the Tensile strength increased slowly till 25 %. It is found that the tensile strength declined as the fiber concentration in composite increased. The increase of fiber-to-fiber interaction and dispersion problem in matrix has contributed to this phenomenon

Flexural strength and hardness also increases up to 25% and then starts decreasing.

Finally to summarize everything, coconut coir fiber has enhanced tensile properties, flexural as well as impact properties of the unsaturated polymers. The study has demonstrated the optimum for peak performance for tensile and flexural testing at 25 % of fiber content.

FUTURE WORKS

The results of this study suggested a number of new avenues for research in future. They are:

- Determination of chemical constituents inside the local abundant coconut coir fiber to the extent of chemical content and its effects to certain properties.
- The work should be extended to study other properties such as creep, fatigue, compressive, shear strength, chemical resistance and electrical properties.
- The usage of different types of chemical promoters and coupling agents can be studied.
- Other epoxy-hardener polymeric matrix system can be studied.
- Hybrid composite comprising other fiber (such as glass fiber) with coconut coir fiber can be studied as this will definitely yield better performance of composite system.
- The above results can be more precise by optimizing the above data.
- Chemical treatment of fibers can be done. It can improve the mechanical properties of the composite.
- Different composites can be prepared with different length of fibers. Length can be a factor in improving the mechanical properties of the composites.
- Different composites can be prepared by placing the fibers at different angles. This can affect the mechanical properties of the composites.

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