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Development and Testing Of Natural Fiber Reinforced Composites With Polyester Resin

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Abstract

Now --a – days most of the automotive parts are made with different materials which cannot be recycled. Recently European Union (E.U) and Asian countries have released stringent norms concerning automotive end-life requirements i.e the parts of the automotives should be recycled. This increased the use of natural fibres in composite materials. Natural fibers have recently become more attractive to researchers, engineers and scientists as an alternative reinforcement for fiber reinforced polymer composites. Due to their low cost, low density, stiffness, fairly good mechanical properties, high specific strength, non-abrasive, eco-friendly and biodegradable characteristics, they are exploited as a replacement for the conventional fiber, such as glass, aramid and carbon. The tensile properties of natural fiber reinforced polymers (both thermoplastics and thermosets) are mainly influenced by the interfacial adhesion between the matrix and the fibers. Further the mechanical properties can be improved with several chemical modifications on the composites. In the present work, natural fiber (sisal, hemp, hemp and sisal combination) reinforced polyester resin composites were produced and are tested for mechanical properties and further compared with the normal plastics. The mechanical properties of sisal and hemp reinforced polyester resin composites were found to increase with increasing fiber weight fraction. In important properties hemp and sisal combination composite showed the best.

Keywords: Hemp, Sisal, Polyster resin, Thermoplastics, Thermosets

Introduction

Many of our automotive applications require materials with different combination of properties that cannot be met by the conventional metal alloys. These conventional metal alloys are neither degradable nor recycled. So, now-a-days these are all replaced by composites. These composites are having major applications in aero space, transportation, construction, sports, packaging etc. Besides good corrosion resistance, composite materials exhibit good resistant to extreme temperatures and wear especially in industrial sectors. The fiber reinforced polymer (FRP) is a composite material with high strength fibers such as glass, aramid and carbon [2]. Normally the polymers are classified into two types. Those are thermoplastics and thermo settings. The most commonly used thermoplastics are poly vinyl chloride (PVC), while epoxy resins are the commonly used thermo settings. Now-a-days this epoxy resin attracted many researchers due to their advantages over the conventional fibers like glass and carbon fibers [4].

Composite materials (composites) are made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct within the finished structure. Generally these composites are made of matrix and reinforced materials. The matrix material supports the reinforcement materials by maintaining their relative positions. The reinforcements impart special mechanical and physical properties to the matrix material. Depending upon the composition of these two constituents in the composites the strength of the material will vary [3, 6]. So the designer of the automotive products can choose an optimum combination of these composites for their requirements.

The role of matrix in a fiber-reinforced composites are (i) To keep the fibers in place (ii) To transfer stresses between the fibers (iii) To provide a barrier against an adverse environment such as chemicals and moisture (iv) To protect the surface of the fibers from mechanical degradation.

Fibers are the principal constituents in a fiber - reinforced composite material .They occupy the largest volume fraction in a composite laminate and share the major portion of the load acting on a composite structure. So for particular application selection of fiber type is important because it influences the characteristics of the composite laminate like density, strength, conductivity

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and cost. Natural fibers such as banana, cotton, coir, sisal, hemp and jute have attracted the scientists and technologists for the various applications [4]. Li et al. [5] reported that flax fiber content from 10-30% by mass was mixed with high density polyethylene (HDPE) by extrusion and injection moulding to produce composites. The results showed that increasing fiber content increases the mechanical properties up to 20% by volume and then it dropped. Khoathane et al [1] found that the tensile strength and young's modulus of composite reinforced with hemp fibers increased incredibly with increasing fiber loading. It has been concluded from the mathematical modeling that the predicted and experimental tensile strength of natural fibers are very close to each other.

Among all hemp and sisal are best and in the present work the composite material is produced with these plants and evaluated various mechanical properties. The main advantages of them over the other conventional are low cost and mechanical properties and biodegradable tendency [3] but the major drawback of natural fiber composite is its incompatibility between natural fibers and thermoplastic materials. This leads to the undesirable properties in the composites. So some chemical treatment is necessary to improve the adhesion characteristics between the fiber and matrix. Hu and Lim [7] investigated that alkali treatment improved the tensile properties of hemp fiber reinforce polylactic acid (PLA) compare to those untreated. Liu et al [8] evaluated the effects of different fiber surface modifications with NaOH and concluded that the surface modifications could remove surface impurities, increases surface roughness and tensile strength.

Materials and Methods

The raw material selected for the present experimental work is sisal fiber, hemp fiber as reinforced components and accelerator (Cobalt naphthenate- speed up the chemical reaction), catalyst (methyl ethyl ketone peroxide – speeds up the curing of the compound), releasing agent (Cellophane, wax paper and PVA water soluble release agent) and styrene monomer (after removing the inhibitor) were used as matrix components. The present experimental work consists of two phases namely

1. Preparation of the composite material
2. Testing of the composite material.

Preparation of the composite material

In the present work the composites were produced using sisal and hemp fibers. The steps involved in this experiment is

Chemical Treatment

- Fibers are extracted from sisal & hemp plants by cutting the leaves stem that are close to the ground.
- These sisal and hemp fibers are chemically treated with two different types of chemicals namely hydrogen peroxide and NaOH at various concentration levels. The purpose of chemical treatment is to remove the moisture content in sisal and hemp fibers and to increase their tensile strengt.
- These fibers were pre-treated with alkaline solution which is prepared in different concentration of NaOH for an hour under constant stirring and 24 hours at room temperature and then dried in open air for 7 to 8 days. With this the moisture content in the fiber will be completely removed.
- Then these extracted fibers are allowed to dry and they are packed in air tight covers as shown in the following figure

Figure 1: Fibers after chemical treatment

Fabrication of Composite

The composites were produced with sisal and hemp fiber as a reinforcement and methyl ethyl ketone peroxide (MEKP) as a catalyst and other chemicals (mentioned above) as a matrix material. With the previous literature available it is concluded that the mechanical properties of the composites are mainly influenced by the fiber content in the composites. So the composite is prepared as per the dimensions proposed in the literature in the following manner.

Preparing the glass mould for the fabrication of composites

The test specimens were prepared with different sample composites for compression test, tensile test and flexural

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test .The glass mould of dimensions are 300 x 200 x 4 mm and a mould cavity of 120 x20 x 4 mm is made by fixing 4 mm thick glass plates of width 15mm and thickness 4mm on four sides of the plate using araldite. The mould has to be solidified in normal temperature. The post curing process will be done in furnace by maintaining the temperature 70 ^{0}C.

He mould selected for the preparation of resin must be cleaned and dried; otherwise it may cloud the resin. Then apply the release wax and allow it to dry so that the casting can be removed easily (Figure 2).

1) The mould selected for the preparation of resin must be cleaned and dried; otherwise it may cloud the resin. Then apply the release wax and allow it to dry so that the casting can be removed easily (Figure 2)

2) 100 parts of unsaturated polyester resin was taken and 0.5 parts of accelerator and catalyst were added to the mixture.

3) The fibers were cut into required size and weighed accurately in each case. The sample plates prepared by varying the weight of fibers.

Figure 2: Preparation for mould pouring

4) First pour the polyester resin in to the jug and then stir the resin with a stirrer. After few minutes catalyst of blue colour liquid is mixed in the resin so that we can get blue colour to the composite.

5) In order to dry the mixture accelerator is mixed to the resin so that we obtain the liquid and the same is poured in to the mould.

6) Close the mould with a glass plate and put the weight on the mould. Within the next six hours precuring will be done for the solidification of the resin.

7) Then post curing is done for 3 hours in the vacuum furnace for the reduction of brittleness of the composite. This increases the bonding of matrix and reinforced materials (figure 3)

8) Figure 4 shows the finished composite material after removing it from the vacuum furnace

9) Then the materials are tested by using tensile test and flexural test by using universal testing machines

Figure 3: Preparation of resin Post Curing

Figure 4: Finished Composite

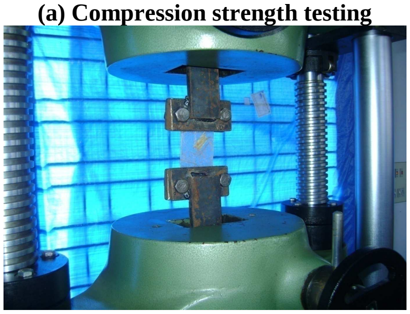
As per the previous literature available the combination of 75% hemp and 25% sisal showed the best results when tested with various combinations of hemp and sisal. So in the present work test specimens are prepared with 75% hemp and 25% sisal combination and are tested. These are further tested with plain (normal) plastics without any catalyst and accelerators etc.

Testing of Composites

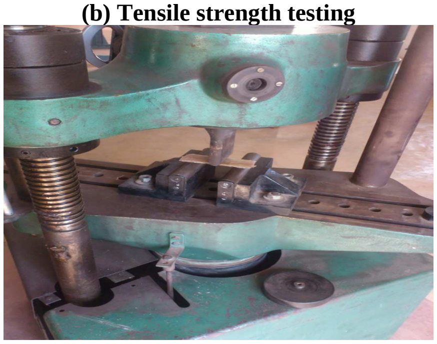
In the present experimental work the composite material is fabricated using hand moulding method. The test specimens are prepared with standards and were tested to evaluate the mechanical properties like tensile strength, compression strength and flexural strength.

A specimen of the prepared composite material is tested with compression testing machine for ultimate compression strength, universal testing machine for ultimate tensile strength and flexural strength. The test specimens are held in the machines (as shown in the figure 5) and the load is applied. The load at which the composite material failure occurs is noted down for the further discussions.

(a) Compression strength testing



(b) Tensile strength testing



(c) Flexural strength testing

Figure 5: Composite Testing

Results and Discussions

Untreated fiber strengths

In the present experimental work the natural fiber reinforced composites of hemp, sisal and the combination of hemp and sisal (75% hemp + 25% sisal) are developed and tested for the mechanical properties. This is further compared with the normal plastic without any resin, catalyst and accelerator etc.,The results are presented below.

Compression strength

The compression strength of the composite depends on the type of fiber used and increases with the amount of fiber. The variation of the compressive strength is illustrated in the exhibit 1.The composite made of hemp is having more strength compared to the sisal composite.

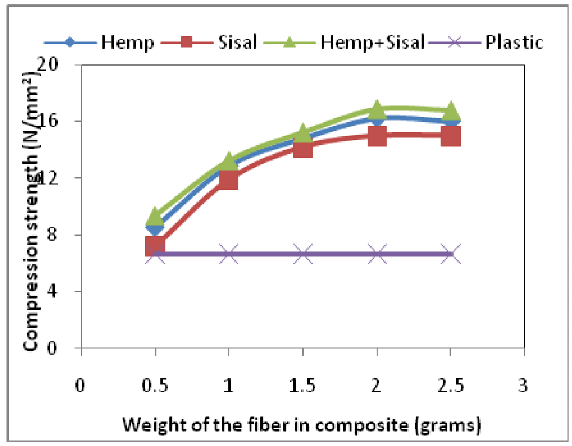


Exhibit 1: Variation of compressive strength with the weight of the fiber in composite

The plain plastic without any fiber is brittle and will lose its mechanical properties within short time. The compressive strength of the normal plastic is 6.68 N/mm^2. The compressive strength of the hemp is 142.5%, 124.2% higher than normal plastic. Any way the strength of the composite further increases with the combination of hemp and sisal and is 153% higher than that of normal plastic.

Tensile properties

The mechanical property of the composite relies on the type of fiber and matrix used. This further depends on the quantity of the fiber content. The tensile strength variations of the composites are shown in the following exhibit 2. Compared to the composites made with untreated fibers, the

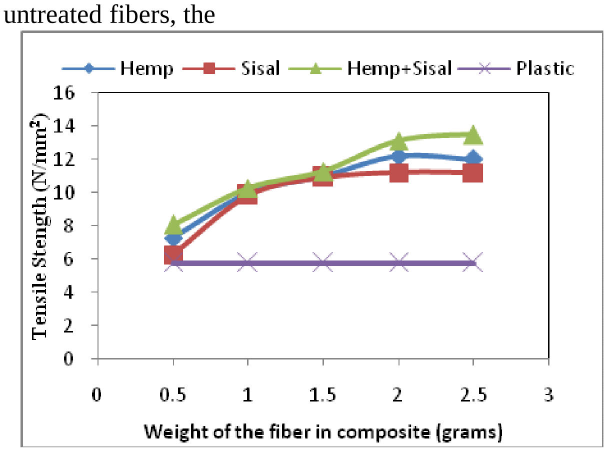


Exhibit 2: Variation of Tensile strength with the weight of the fiber in composite

The improvement in the tensile strength of composites was 110% for hemp and 94.45% for the sisal fiber. This strength of the fiber further increases with the combination of hemp and sisal fiber. The strength is 128% higher than untreated fibers. This improvement is because of surface modification which improves the matrix adhesion property between the matrix and fibers.

This could be due to the better dispersion of fibers and interaction between the matrix and fibers and reaction of the catalysts and other agents with the fibers. Therefore this indicates that the chemical treatment of the fibers significantly increased the adhesion characteristics and further mechanical properties.

Flexural Properties

The variation of flexural properties of the composites is shown in the exhibit 3. With the results it is concluded that the introduction of the fiber increases the flexural strength compared to the untreated fiber. Due to the chemical treatment of reinforced surface with catalyst and other agents the bonding strength between the fiber and matrix material is improved. However the bonding strength of the sisal fiber is less than hemp. The improvement in the bonding strength is higher with the combination of hemp and sisal fiber. This improvement is 2.2% and 4.14% respectively compared with the sisal fiber. From the above fig. it is also observed that the composites could transfer the stresses effectively from the matrix to the fibers. The treatment of the fibers modified the surface energy and the tension of the fibers and this further improves the molecular chain reactions. The effect of the chemical treatment on the composites can be observed by comparing the results of the above composites which reveals that these composites are much more stronger than untreated fibers.

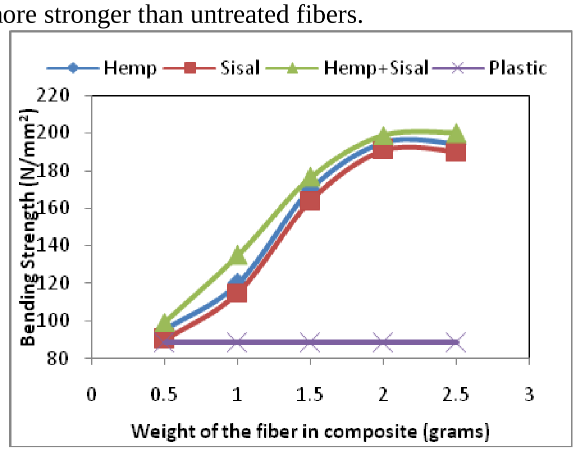


Exhibit 3: Variation of bending strength with the weight of the fiber in composite

Conclusions

The serious problems that the scientific world facing are the development of new methods for the treatment of solid wastes, particularly with non-natural reversible polymers. The method of processing of these wastes is cost-effective and will produce harmful chemicals. So, one has to concentrate on the natural fibers which are originated from the plants. In this paper I discussed about the natural fibers, hemp and sisal which are produced from the plants. These natural fibers are renewable and made available within the short period as compared with traditional glass and carbon fibers for making the advanced composites. Finally it is concluded that the natural fibers are low cost, recyclable, low density and eco-friendly material. Their mechanical properties are very good and can be used to replace the conventional fiber such as glass, carbon in reinforced plastic material. Further, chemical modification methods were adopted to improve the fiber –matrix interfacial bonding and to enhance the mechanical properties. This surface treatment improved the compatibility of the fiber and matrix and the effective stress transfer between the reinforced material and matrix. It is also clear that the strength and stiffness of the natural fiber polymer composites is strongly depends on the quantity of the fiber. This strength will increase up to certain amount of fiber and further it will decrease. Up to the optimum value of the fiber weight ratio, the load is uniformly distributed on all fibers which are well bonded with the resin matrix material. Further increment of the fiber content may cause for uneven load distribution. With the present work it is concluded that though the hemp is having higher tensile properties than sisal, this tensile strength can be further improved with the combination of hemp (75%) and sisal (25%).

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