P: ISSN NO.: 2321-290X RNI : UPBIL/2013/55327 VOL-6* ISSUE-9*(Part-2) May- 2019
E: ISSN NO.: 2349-980X **Shrinkhla Ek Shodhparak Vaicharik Patrika**

Fabrication and Characterization of Natural Fiber Reinforced Epoxy Based Hybrid Composite

Abstract

With the development and advancement of composite materials, these materials have found their use in every sector of manufacturing. Fiber reinforced composites falls in the same category with diverse uses. But their non degradable nature has started to cause a concern. One solution in quest of replacement of fiber is the use of natural fibers. A lot of work has already been done to check the feasibility of this replacement. The observations and the results suggest that natural fibers is the right solution to this environmental problem, with some limitations.

This work exhibits the fabrication and characterization of epoxy-based reinforced composite with a mixture of hemp (*Cannabis sativa*) and glass fiber.

A. K. Singh
Assistant Professor,
Deptt. Of Mechanical Engineering Agra College,
Agra, U.P., India

Saroj Singh Chahar
Assistant Professor,
Deptt. of Botany,
RBS College,
Agra, U.P., India

Keywords: Composite, Hybrid, Natural Fiber

Introduction

Composite materials, both natural and manufactured, are found in a multitude of applications in today's world. From building materials, automobile components, and medical devices to aircraft bodies and spacecraft, composites are used almost everywhere.

A composite is a combination of at least two materials, each of which maintains its identity in the combination. Combinations of synthetic polymers with advanced engineering fibers, or plant fibers as amalgamations of the natural polymers, cellulose, hemicelluloses, and lignin, provide examples of sophisticated composites. Materials such as wood are viewed as a polymer composite of nature as opposed to polymer composites manufactured via chemical syntheses. Composite may be defined as: "Composites are artificially produced multiphase materials having a desirable combination of the best properties of the constituent phases. Usually, one phase (the matrix) is continuous and completely surrounds the other (the dispersed phase)".

The primary phase is generally responsible for providing the bulk form of the material as a whole. The primary phase encloses or surrounds the secondary phase, and shares or transfers imposed mechanical load to and from the reinforcing phase. The reinforcing or secondary phase material may be in the form of discontinuous flakes, particles, fibers, whiskers, or nanoparticles. Alternatively, the reinforcing phase may be of a continuous nature, that is, as long fibers or woven mats of fiber.

Generally, a "fiber" is an object that is elongated, with a length-to-diameter (L/D) ratio of somewhat greater than one.

Natural Fibers

One may think of natural fibers as any fibrous material that is extracted from the environment, be it a fiber derived from plant, animal, or mineral sources. Natural fibers may be processed by hand, simple tools, or sophisticated industrial processes to render them useful for some purpose, but they are clearly distinguished from manufactured fibers that are synthesized. Rayon fibers, for example, are reconstituted chemically from the cellulose obtained from plants, but they are not generally viewed as "natural fibers" because of the degree of chemical processing required to form them. Similarly, fibrous materials generated from petrochemicals and carbon are obviously made from materials found in the environment, but since the raw material are not fibrous in their native state and are not extracted directly from living organisms, they are not considered as natural fibers. Here the term "natural fiber" refers to fibers obtained from botanical sources.

Most vegetable fibers contain, in varying chemical composition and content, the organic structural polymers cellulose, hemicelluloses and lignins. Natural fibers are rich in cellulose, abundantly available and easy to handle and process.

With the recent increase in environmental awareness, exploiting natural fibers has raised great interest and become of importance.

The main advantages of natural fiber composites are:

1. Production cost is low and these are easily available.
2. Due to its low specific weight, it has higher specific strength and stiffness than glass fiber.
3. The production requires little energy, and CO_2 is used while oxygen is given back to the environment therefore it is a renewable source.
4. Low wages countries accept natural fiber because product can be produced with low investment at low cost.
5. It acquires healthier working condition, reduced wear of tooling and no skin irritation.
6. It can be recycled while, glass causes problem in combustion furnaces.
7. It has good thermal and acoustic insulating properties.

Aim of the Study

Composites using synthetic fibers have superior properties but there are numerous hazardous effects attached to them. Taking concerns of those hazardous effects it is necessary to find substitute of the synthetic fibers.This work is an effort in that direction. It aims to develop green composite material using natural fibers.

Review of Literature

A lot of work has been done on these composites studying effects of various parameters on the properties. Researchers have used various methods to fabricate the composites and have tested the specimen in accordance with ASTM and ISO standards. The analysis has been done using various tools available. The results obtained by some are discussed here.

In a study by Goulart et al, the results revealed that the addition of coupling agent in the palm fibers reinforced polypropylene composites is a promising process, as the addition of fibers to the matrix improved the flexural strength and modulus when compared to the pure polypropylene. [Goulart, 2011]

Hitoshi Takagi and Yohei Ichihara conducted a study on the effect of length on mechanical properties of composite using starch based resin and short bamboo fiber. [Hitoshi Takagi, 2004]

Gupta et al. studied the effect of different parameters on mechanical and erosion wear behaviour of bamboo fibre reinforced epoxy composites. It was found that the impact strength increases linearly with increase in fibre loading and then decreases the insignificant amount of energy. [Gupta A, 2011]

In a study by Joshi et al, it was stated that natural fiber production results in lower environmental impacts compared to glass fiber production. [S.V. Joshi, 2004]

Monteiro et al. studied the mechanical performance of coir fibre/polyester composites. The mechanical behaviour of coir fibre/polyester composites which exhibited the lack of an efficient reinforcement by coir fibres is attributed to their low modulus of elasticity, in comparison with the bare polyester resin. [Monteiro S.N., 2008]

Vilay et al. studied the effect of fibre surface treatment and fibre loading on the properties of bagasse fibre reinforced unsaturated polyester composites. Higher tensile and flexural properties were obtained for treated fibre composites compared to those of untreated fibre based composites. The addition of higher amount of fibre results in higher tensile and flexural properties of the bagasse fibre reinforced polyester composites. [Vilay V, 2008]

Yan Li et al studied that sisal fiber is the promising reinforcement because of low density, high specific strength, no health hazards and finding applications in making of ropes, mats, carpets, fancy articles etc. [Yan Li, 2000]

Tensile properties of palm/jute fiber reinforced polymer hybrid composites are carried out by Jawaid et al. They have prepared hybrid natural fiber composites taking palm fiber as skin and jute as core material. They observed that the tensile properties slightly higher for the jute as skin and palm fiber as core material. [M. Jawaid, 2011]

The overall tensile and flexural properties of natural fiber reinforced polymer hybrid composites are highly dependent on the aspect ratio, moisture absorption tendency, morphology and dimensional stability of the fibers used. [M.M. Kabir,2012]

Rao et al. studied the effect of fibres on mechanical properties of bamboo/glass fibre based hybrid composites. It was reported that hybrid composites with alkali treated bamboo fibres were found to possess higher impact properties. [Rao H.R, 2011]

Materials

The raw materials used in this work are:

1. Hemp fiber
2. Glass fiber
3. Epoxy
4. Hardener

Hemp is a distinct variety of the plant species *Cannabis sativa L.* that grows to a height anywhere from 4-15 ft (1.2-4.5 m) and up to 0.75 in (2 cm) in diameter. The plant consists of an inner layer called the pith surrounded by woody core fiber, which is often referred as hurds. Bast fibers form the outer layer. The primary bast fiber is attached to the core fiber by pectin - a glue-like substance. The primary fibers are used for textiles, cordage, and fine paper products. The wood-like core fiber is used for animal bedding, garden mulch, fuel, and an assortment of building materials.

Hemp is refined into products such as hemp seed foods, hemp oil, wax, resin, rope, cloth, pulp, paper, and fuel. Nowadays a modest hemp fabric industry exists, and hemp fibers can be used in clothing. Pure hemp has a texture similar to linen. China is the world's largest producer of hemp fabric, whereas India produces the most hemp overall. Other products made from hemp fiber include: insulation, particleboard, fiberboard, rope, twine, yarn, newsprint, cardboard, paper, horse stable bedding, and compost. Hemp seed is used to make methanol and heating oil, salad oil, pharmaceuticals, soaps, paint, and ink.

Glass fiber, in its various forms, has been the most common reinforcement for polymer matrices. Glass fiber is a generic name like carbon fiber or steel or aluminium. Just as different compositions of steel or aluminium alloys are available, there are many of different chemical compositions of glass fibers that are commercially available. Common glass fibers are silica based (~50–60 % SiO2) and contain a host of other oxides of calcium, boron, sodium, aluminium, and iron. The glass fibers are designated with capital alphabet according to its properties. The designation E stands for electrical because E glass is a good electrical insulator in addition to having good strength and a reasonable Young's modulus; C stands for corrosion and C glass has a better resistance to chemical corrosion than other glasses; S stands for the high silica content that makes S glass withstand higher temperatures than other glasses.

Epoxy resins are a broad family of materials containing a reactive functional group (oxirane ring) in their molecular structure. These resins are unique among thermosetting resins because of their very low shrinkage during polymerization or curing. Epoxy resins are used in protective coatings, adhesives, flooring, civil engineering, electrical and electronics products.

The most widely used epoxy resins are based on the reaction of bisphenol A and epichlorohydrin producing the diglycidal ether of bisphenol A (DGEBA). Bisphenol A diglycidyl ether is not produced as a pure monomer but as a mixture of monomer, dimer, trimer and tetramer.

Epoxy resin must be reacted with a hardener (co-reactant, cross linking agent or catalyst) to become a thermoset resin providing the desired physical properties. Resins with high percentage of epoxy functionality are cured using the epoxide group, while the higher molecular weight DGEBA resins are cured via the hydroxyl groups along the backbone. The major hardeners are aliphatic amines, anhydrides, polyamides, phenol / urea / melamine formaldehydes and lewis acid catalysts. A hardener is usually selected to meet the working requirements of the system and to produce the desired physical properties in the cured products.

Fabrication

The method used for fabrication is the hand lay-up (also known as wet lay-up) technique, where fibres in the form of mat or fabric are placed in an open mould and wetted-out with liquid resin. Curing may be carried out at room temperature or at elevated temperature. Additional elevated temperature post-curing may also be used. A modification of this technique is the spray-up technique where chopped fibres, mixed with resin, are sprayed onto the mould. Another common technique is resin infusion, where resin is infused into a mat or fabric preform under the application of pressure and/or vacuum. Two different types of process are used. The first, known as resin transfer moulding (RTM), utilizes a two-piece closed mould into which the fibre preform is placed and the resin then infused. A simpler process is vacuum bag resin infusion. This uses a single mould into which the fibre preform is placed. A plastic film is then placed over the preform, sealed around the edges to form a vacuum bag, and vacuum then applied to the mould cavity, i.e., the space between the vacuum bag and the mould. The vacuum acts to draw resin into the mould cavity, thereby infusing the preform. These closed mould processes have the advantage over open mould processes of producing more consistent parts and avoiding emission of volatiles from the resin into the atmosphere.

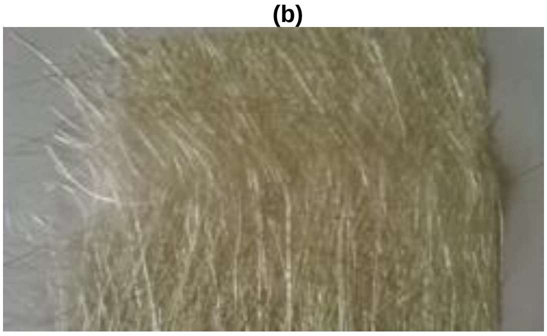
In this work the fabrication of composite slab is carried out by conventional hand layup technique. The multi-length hemp fibre and the E-glass fibres are used as reinforcement and epoxy is taken as matrix material.

The low temperature curing epoxy resin and hardener are mixed in a ratio of 10:1 by weight percentage. Composites of composition having 10 wt% fibre loading and fibre length 16mm, is made. Figure shows hemp fibre and glass fibre respectively. The next figure shows the mould used to fabricate the composite slabs. The cast of each composite is cured under a load of about 40-45 kg for 30 hours. Finally, the specimens of suitable dimensions are cut with the help of hack saw for mechanical testing.

Fig.1 - (a)Hemp fiber, (b) Glass fiber, (c) Mould

(a)

(b)



(c)

Testing of Composites

The tensile test was performed on the samples as per ASTM D3039-76 test standards. The tensile test is generally performed on flat specimens. A uni-axial load is applied through the ends. The ASTM standard test recommends that the length of the test section should be 100 mm specimens with fibers parallel to the loading direction and should be 11.5 mm wide.

Flexural test is to determine the capability of a material to withstand the bending before reaching the breaking point. This test is done on a three point bend test using Instron 1195. Inter-laminar shear test is also performed on the same equipment. A span of 40 mm was taken and cross head speed was maintained at 2 mm/min.

Leitz micro-hardness tester is used for micro-hardness measurement on composite samples. The test is conducted at three points on each specimen and the mean value is considered taken.

Scanning electron microscope of Model SEM LEO-43 was used for the morphological characterization of the composite surface. The samples are cleaned thoroughly, air-dried and are coated with 100 Å thick platinum in JEOL Sputter Ion Coater and observed SEM at 20 kV. A thin film of platinum is vacuum evaporated onto the specimen to enhance the conductivity of the composite samples before the micrographs are taken. The fracture morphology of the tensile fracture surface of the composites was also observed by means of SEM.

Results and Conclusions

Hardness is one of the most important properties that come under investigation during analysis. The results show that the micro-hardness of composite is 124 Hv. As a future work, the effect of length of fibre can be studied by fabricating hybrid composite of various fiber lengths and comparing them for selection.

Fig.2 - Tested specimens for micro hardness

Tensile test results show that the tensile strength of the composite is 86 MPa.

Fig. 3 - Tested specimens for Tensile strength

The flexural strength was found to be 155 MPa.

Fig. 4 - Tested specimens for Flexure strength

Scanning Electron Microscopy is done on the fractured surfaces of the specimen to study the adhesive behaviour of fiber with fiber and fiber with epoxy matrix. The micrographs also provide information regarding the nature of fracture that took place while testing.

The scanning electron micrographs reveal that the adhesion among the components has a good scope for improvement. The hemp fiber is seen dispersed which is due to poor adhesion between the components. The fibers are also seen elongated or pulled before fracture which again is probably due to lower degree of adhesion. It can be inferred from the micrographs that interfacial bonding has scope of improvement which can lead to better strength properties. The lower adhesive forces may also be the result of the technique used for fabrication i.e. hand layup technique. Better fabrication method may result in high degree of adhesion and hence better properties of the composites.

Fig. 5 - Scanning Electron micrographs of specimen after Tensile test

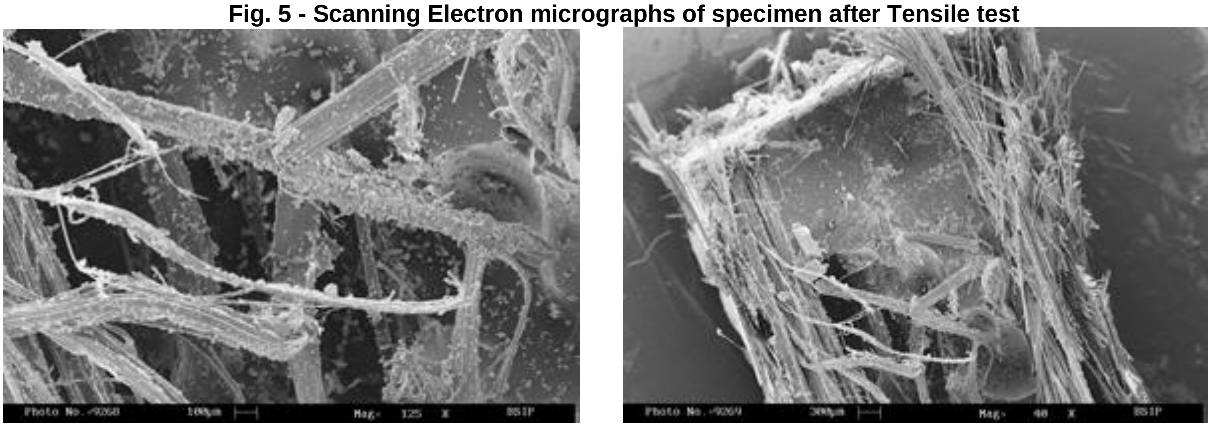
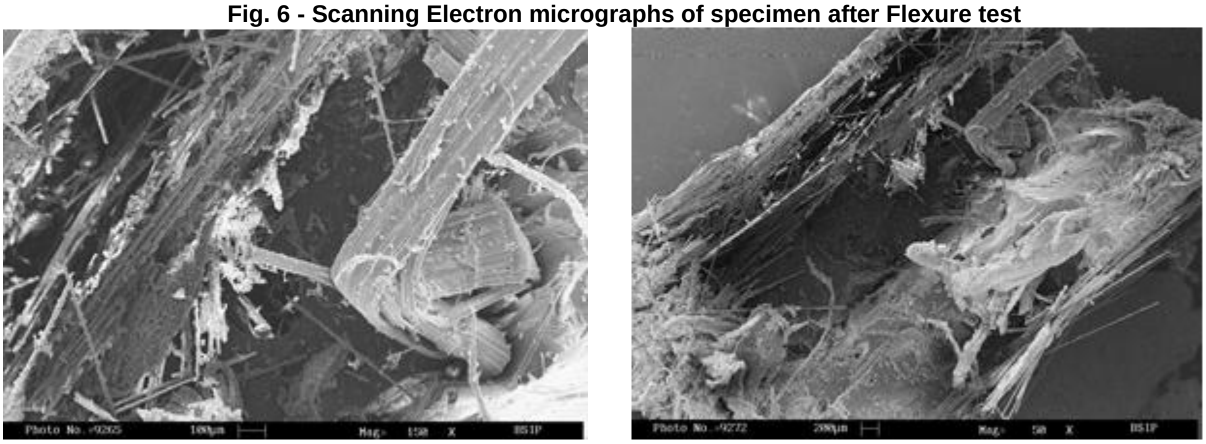


Fig. 6 - Scanning Electron micrographs of specimen after Flexure test



In this work, hemp / glass fiber reinforced epoxy based hybrid composite is successfully fabricated using hand layup technique. The properties of the fabricated composite were checked and were found satisfactory. Though the properties were not as appropriate as in synthetic fiber but this composite can still be used in vast number of applications where load requirement is not high.

The pictures of fractured surfaces of composite specimens taken by scanning electron microscopy machine provide information about adhesion between both types of fiber and between fiber and epoxy matrix.

Work may be done on effect of length of fiber, orientation of fiber, treatment of fiber with different chemicals to enhance adhesion, use of other fillers etc. Taking in view of all these facts, there is wide scope for development of hybrid composites with better physical and mechanical properties.

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