Effect of Natural Fiber Loading on Abrasive Wear Behaviour of Morning Glory Tree Reinforced Epoxy Composite

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Abstract: *Growing environmental concern and regulations are shifting the designer's choice from synthetic fiber reinforced composite and plastics to natural fiber composites. Polymeric materials reinforced with synthetic fibers such as glass, carbon, and aramid provide advantages of high stiffness and strength to weight ratio compared to conventional construction material like wood, concrete and steel. The promising application of natural fibers in composite applications is packaging, decking, interior panels and furniture. Due to its high specific strength and modulus natural fibers are emerging as promising reinforcement material for fiber reinforced polymer (FRP) composites. Numerous possible material combinations, unique self-lubrication capabilities and low operating noise make the FRP composites a potentially better material over conventional metallic materials for tribological applications. Observing the tremendous advantages and opportunity of natural fibers there is a need to further explore the possibility of new fibers to be used as reinforcement in polymer composites for tribological applications. Ipomoea carnea, locally called as "Amari" is one such natural resource found abundantly in many parts of India, whose potential as fiber reinforcement in polymer composite has not been explored till date. Ipomoea carnea is a gregariously growing short shrub available all over the world. The plant is native of South America and was introduced in to India as an ornamental plant. Cellulose content of this shrub is over 55% and lignin content is about 17% which indicates it is a fibrous material and can be used as filler for making light weight polymer composite which provides an effective means of utilization of a large quantity of this diffuse shrub. Literature indicates that no significant work has been done on this shrub other than its stems are used for developing housing element in rural India without any pre-treatment resulting non-durable structure. Hence in this present work an attempt has been made to prepare and study the mechanical and abrasive wear behavior of morning glory tree reinforced epoxy composite, with different concentration of particulates.*

Keywords: *Natural Fibers, Composite Materials, Polymer Composites, Tribological Applications, Reinforcement Material, Mechanical And Abrasive Wear Behavior.*

I. INTRODUCTION

The wonder materials Composites, with light weight, high strength to weight ratio and stiffness properties has replaced most of the metal and alloys in recent times. Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. Generally, fibers are the principal load carrying members, while the matrix keeps them at the desired location and orientation, acts as a load transfer medium between the fibers, and protects them from environmental damages. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in improved or better properties. Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. The concentration distribution and orientation of the reinforcement also affect the properties.

A. Chemical composition of natural fibers

The proportions of constituents of any natural fiber vary with origin, area of production, variety and maturation of plant. The major constituent of a fully developed natural fiber cell walls are cellulose, hemicellulose, lignin and pectin. These hydroxyl-containing polymers are distributed throughout the fiber wall [1].

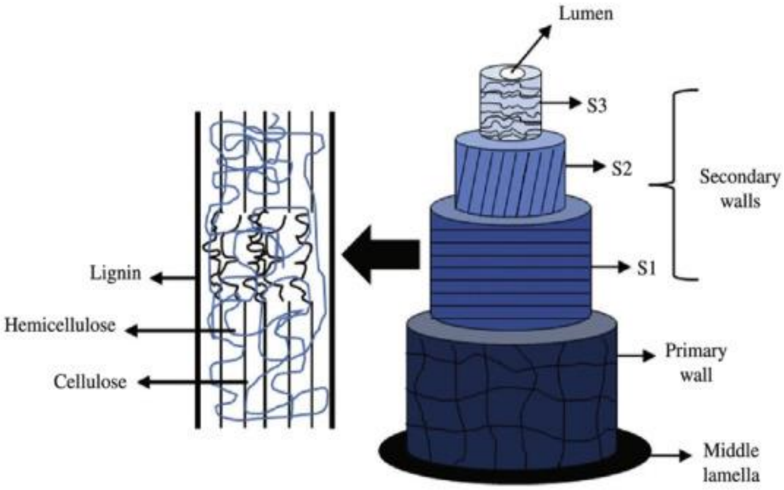

Figure 1. Structure of an elementary plant fiber (cell)

B. Natural Fiber

There are many potential natural resources which India has in abundance. Most of them come from forest and agriculture. Observing the tremendous advantages and opportunity of natural fibers there is a need to further explore the possibility of new fibers to be used as reinforcement in polymer composites for mechanical and tribological applications. *Ipomoea carnea*, locally called as "Amari" is one such natural resource found abundantly in many parts of India.

Table 1.1: Chemical composition of *Morning glory tree*chips

SL. No	Components	% composition
1	Cellulose	57.73
2	Lignin	16.59
3	Pentosan	17.30
4	Ash	6.45
5	Silica	0.16

Visualizing the luxuriant growth and vigorous survival of this weed, researchers worldwide are trying to find out the potential economic value for its utilization into value added products and effective method for its management. Therefore the main objective of thiswork is to prepare a Polymer Matrix Composite (PMC) using epoxy resin as matrix material and *Morning glory tree* fiber as reinforcement besides its traditional use.

Figure 2. Photographs of *Morning glory tree* plant

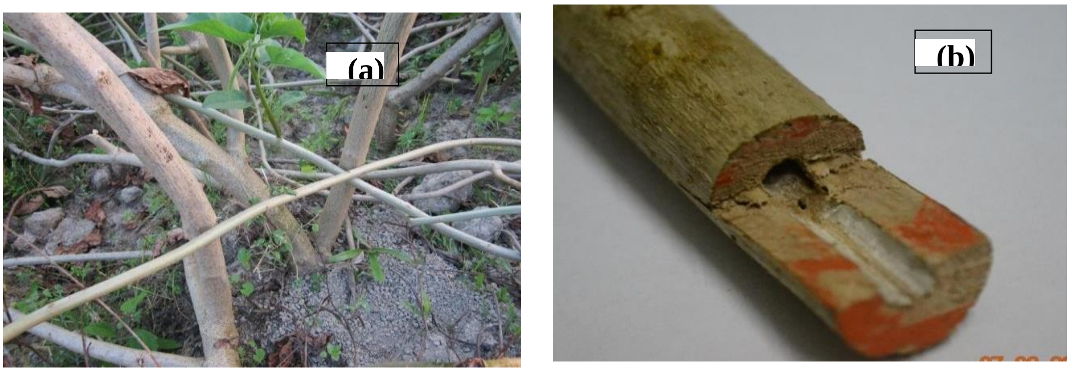

Figure 3. (a) Stem of *Morning glory tree*,(b) Cross section of *Morning glory tree* stems

II. LITERATURE REVIEW

In the recent years, natural fibers such as hemp, flax, jute, linen, kenaf, oil palm and bamboo have been drawn considerable attention in numerous applications, e.g. automobiles, furniture, packing and construction. This is due to their superior advantages over synthetic fibers in terms of relatively low cost, low weight, less damage in processing equipment, improved surface finish of moulded parts composite, good relative mechanical properties, abundant and renewable resources.

From mechanical point of view, natural fibres may enhance mechanical properties of polymers with some considerations and improvement to the surface characteristics natural fibre. There are several factors related to the natural fibres which influence the performance of the composites such as the interfacial adhesion, the orientation, the strength, physical properties, etc. The mechanical efficiency of the fibre-reinforced polymer composites depends on the fibre–matrix interface and the ability to transfer stress from the matrix to fibreas reported by many researchers, [9–20]. Moisture absorption

Most of the industrial and manufacturing parts are exposed to tribological loadings such as adhesive, abrasive, etc. in their service. Therefore, tribological performance of materials becomes an essential element to be considered in design mechanical parts. In other words, understanding the tribological behavior of natural fibre/polymer composites has an equal role to be considered with the mechanical properties of those materials.

For the frictional behavior of those composites, there are four catrogery of frictional trends. In [35, 29, 32], there is increase in the friction coefficient at the running in stage and then followed by the steady state. This indicates the stability of the rubbed surface characteristics. In [28, 32, 33], there is reduction in the friction coefficient in the steady stage compared to the running in, and this is due the smooth film transfer generated in on the counter-face and its high stability.

K.H. Shaltout et al [36] in his second article about the review of Egyptian woody perennials has provided an overall review of the literature dealt with *Morning glory tree* population, depicting the ecological conditions of its habitats, evaluating its adaptability to different environmental conditions, identifying the gaps in the existing information, and focusing the attention of the biologists for filling these gaps.

Khalid et al [37] studied the anti-inflammatory activity of aqueous extracts of *Morning glory tree* leaves and found that the aqueous extract of *Morning glory tree* leaves possesses anti-inflammatory property with the dose dependent effect carried out on experimental model. Between the two doses studied, aqueous extract of *Morning glory tree* at a dose of 500mg/kg was found to possess better anti-inflammatory activity as compared to Etoricoxib. However, further phytochemical studies are needed to isolate the active compound(s) responsible for the pharmacological activities.

It is described to have stimulatory allopathic effects. Its roots are boiled to use as laxative and to provoke menstruation. It was used as a treatment for skin disease by traditional healers. The milky juice of plant has been used for the treatment of leucoderma and other related skin diseases. It has depressant effect on central nervous system. Alsoshows muscle relaxant property [38].

Nandkumar et al [39] also explored its paper making properties. The reactive group ofthe lignin of *Morning glory tree* upon investigation was found to be almost similar to other species, which indicated that it contains all those features of other hard wood and soft wood lignin for paper making process.

Dutt et al [40] reported that a proper blend of *Morning glory tree* and Cannabis *sativa* can produce a stronger paper while the former acts as brightness improver. Thus it can beused as substitute to softwood for soda pulping. His studies revealed that high calorific value spent liquor of *I. carnea* and *C. sativa* with very low silica content is advantageous factor towards energy conservation.

Available literature on *Morning glory tree,* on its suitability in various engineering fields are negligible. Therefore in the present work an attempt has been made to study the mechanical and abrasive properties of the *Morning glory tree* reinforced composite.

III. METHODOLOGY

A. Materials Used

The raw materials used for the present work are

1. Morning glory tree powder
2. Epoxy resin
3. Hardener

B. Morning glory tree powder

Morning glory tree stem was obtained locally. The outer skin layer was scraped out with the help of scissor without damaging the fiber surface. Then it was split into two halves. The inner portion was a hollow structure filled with spongy mass. The spongy mass from the hollow structure was removed and allowed to dry for one day in room temperature. The stem was then chopped into short pieces and was then dried in an oven at 60°C for 4 hours. The chopped pieces were then grinded into fine powder using ball bill. The collected powder was sieved using a sieve shaker. Separate sieve mesh sizes were used to obtain a distribution of particle sizes resulting from the crushing. Table 3.1 shows the particle distribution according to their sizes. The particle size chosen for the experiment was 100 microns due to its highest weight percentage among all sizes.

Table 1. Particle size

Sample	Size range - micron size	Size range + micron size	Weight (grams) approx.	Weight %
1	------	70	20	20
2	7 0	100	40	40
3	100	120	22	22
4	120	200	10	10
5	200	400	8	8
Total			100	

C. Epoxy Resin

The type of epoxy resin used in the present investigation is Araldite LY-556 (Bisphinol- A-Diglycidyl-Ether) which chemically belongs to epoxide family. The following are the notable properties of the matrix.

- Excellent bonding with different materials.
- Highly inert to chemical and atmospheric attack.
- Great dimensional stability.
- Low internal stresses.
- Good mechanical and electrical properties compared to other thermoset plastics.
- Nontoxic, Odourless, tasteless and bio degradable.
- Insignificant shrinkage.

D. Testing of Mechanical Properties of Composite

Tensile Strength

The tensile test is generally performed on flat specimens cut in the shape of dog-bone.The standard test method as per ASTM D3039-76 was used. The length of the test specimen used was 140 mm and with an average thickness of 4 mm. The tensile test is performed in universal testing machine (UTM) Instron 1195. The tests were performed with a cross head speed of 2mm/min. For each test composite of five samples were tested and average value was taken for analysis. Fig 3.2 (a) and (b) shows the UTM machine and the sample in loadingcondition. The results of tensile testing are shown in table 3.3.

Figure 4. Instiron 1195

V. RESULT AND DISCCUSION

The density test results for various specimens which were prepared with *Morning glory tree*particles with different volume fraction are plotted in figure 3.5. It is clearly seen that with the increase in fiber content from 10 to 40 wt % there is a decrease in the void fraction. However in all the composites the volume fraction of voids are reasonably small (<1.00%) The relative proportions of matrix and reinforcing material in a composite decides the density of the composite and density is one of the important factors which determine the properties of the composites. The void content in a composite significantly affect some of the mechanical properties and even the performance of the composite in actual work place. If the void content is higher it results to lower fatigue resistance, greater exposure to water penetration, and weathering [46]. The knowledge of void content is very much essential for estimating the quality of the composite.

Morning glory treeas seen from the present investigation can be used as an effectivereinforcement in polymeric composite creating a variety of technological applications beyondits traditional uses. It can also be used as a substitute for wood based composite. Thecomposite prepared have low density compared to synthetic fibers and also to some natural fibers. Therefore it can judiciously be used for producing light weight composite materials. Reinforcement of Morning glory tree particulate into the epoxy matrix shows improvement in both the tensile and flexural properties compared to pure epoxy.

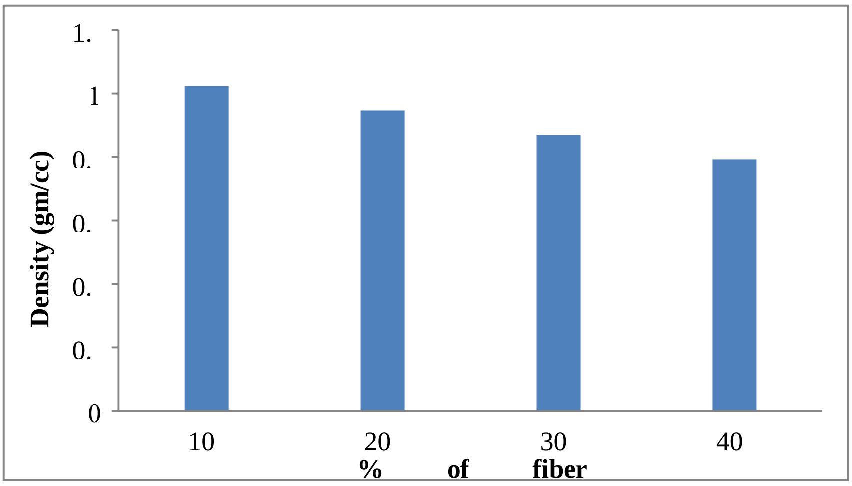

Figure 5. Variation of density with fiber content

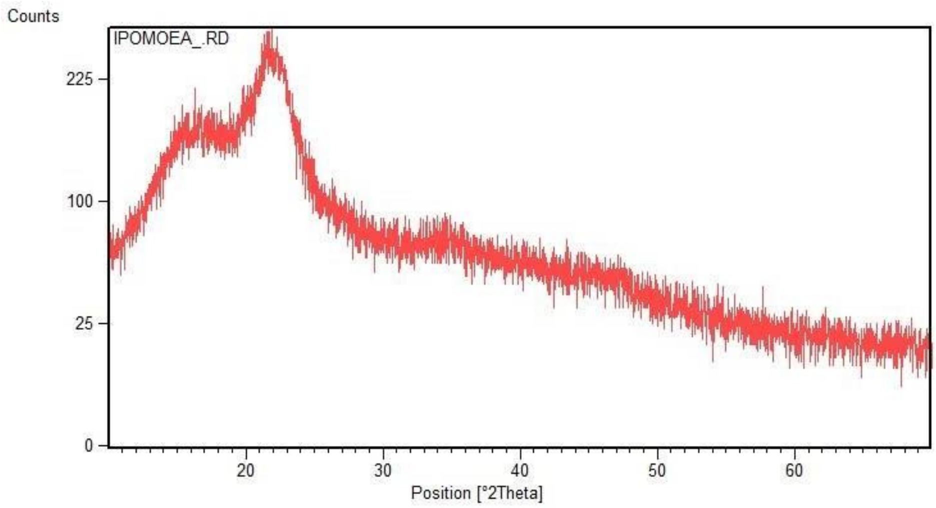

Figure 6. X-Ray profile of *Morning glory tree* powder

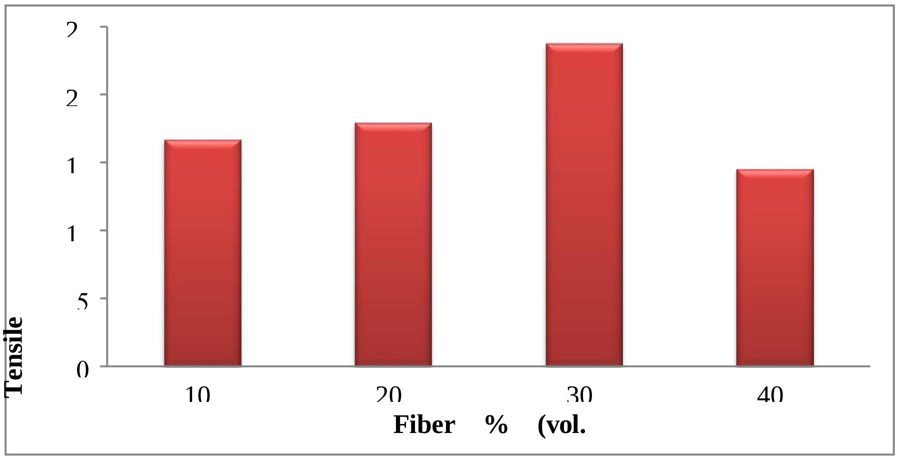

Figure 7. Effect of fiber loading on Tensile Strength

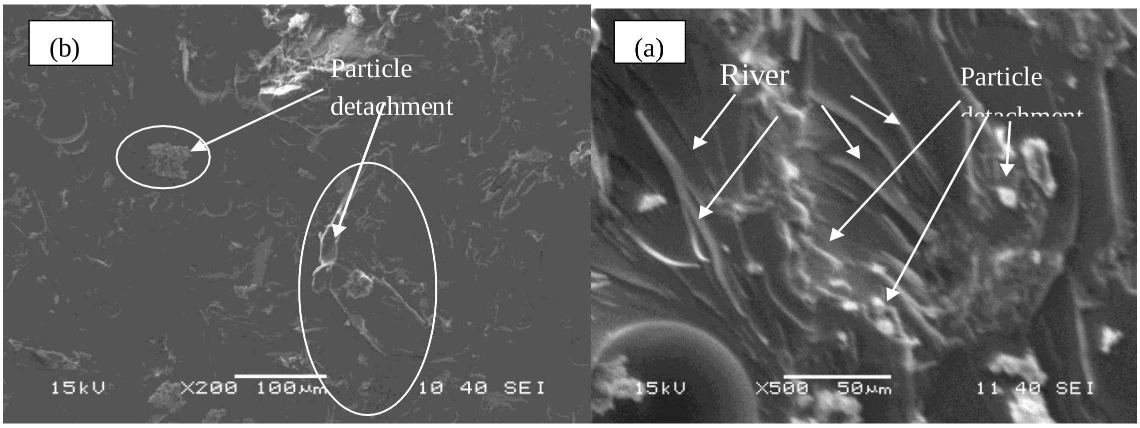

Figure 8. (a) SEM micrograph of 30wt% tensile specimen (b) SEM micrograph of 40 wt% tensile specimen

V. CONCLUSION

The following conclusions can be drawn from the experimental studies of *Morning glory tree* particulate filled epoxy composite:

1. *Morning glory tree* is a well-known weed which is hazardous to animals and its accompanying species. It

can successfully be utilized to produce composite by suitably bonding with resin for the development of value added products.

2. The composites prepared were of low density compared to pure epoxy so it can be regarded as a useful light weight material. The density of the composite decreases with the increase of fiber content.
3. On increasing the fiber content, the strength and modulus of the composites increases. Thirty volume percentage of reinforcement fiber gives the best combination amongthe tested specimen.
4. The incorporation of *Morning glory tree* into epoxy can significantly reduce abrasive wear loss. The optimum wear resistance property was obtained at a fibre content of 30per cent weight fraction. However, excessive addition of fiber (40%) results in drawing out of the fiber from the matrix resin during the test due to poor interfacial adhesion.
5. Abrasive wear is very sensitive to normal load compared to sliding velocity and increases marginally with increasing sliding velocity.
6. With increasing sliding distance, wear rate gradually decreases and attains an almost steady state in multi-pass condition.

The specific wear rate of the composite decreases with an increase in sliding distance because the space between the abrasive is filled by the debris, which reduces the depth of penetration of abrasive particles into the composite sample.

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