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MECHANICAL PROPERTIES OF MILKWEED FIBER REINFORCED COMPOSITES

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ABSTRACT

The natural fiber reinforced polymer composite materials has gained importance in industrial applications as well as in fundamental research. Natural fibers have recently become attractive to researchers, engineers and scientists as an alternative reinforcement for fiber reinforced polymer composites. Due to their low cost, fairly good mechanical properties, high specific strength, nonabrasive, eco-friendly and bio-degradability characteristics, they are exploited as a replacement for the conventional fiber such as glass, aramid and carbon. The present investigation deals with the most uncommon milkweed fiber reinforced epoxy composites. The milkweed fiber is characterized by very low density, high strength and widely available in southern parts of india. The composites are fabricated by reinforcing 5%, 10%, 15% and 20% milkweed fiber by weight in epoxy matrix. The composites are characterized by testing the mechanical properties as per the standards. The possibility of using the stems of milkweed plant as a source for natural cellulose fibers was explored in this research. The mechanical properties such as tensile stress, flexural stress, hardness, impact and density are evaluated.

Keywords: composites, natural fibers, milkweed fiber, reinforcement, epoxy matrix, mechanical properties.

I. INTRODUCTION

The natural fiber reinforced polymer composites are becoming more popular nowadays because of the availability of wide variety of natural fibers in the nature [1]. The natural fibers available are replacing the glass fibers to some extent. The use of locally available fiber for reinforcement in the polymer composites not only increases the local economy but also provides other benefits like reduction in pollution, reduces the production cost, increases the biodegradability of disposed composite articles, etc. The natural fiber reinforced polymer composites are used for automotive, sports, structural, domestic and lower end aerospace applications. The main advantage of the natural fibers is their renewability and high specific strengths [2].

Natural fibers have cost and energy advantages over traditional reinforcing fibers such as glass and carbon. Properties of composites are greatly depended on the volume percentages of fibers and resin. The quality at fiber matrix interface should be improved. Proper fiber surface treatment should be developed and implemented. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry [3].

The feasibility study of applying Milkweed bark fibers as an alternative raw material for fiber-reinforced composite investigated. The chemical analysis of the bark fibers indicates that their main components are holocellulose 76%, cellulose 57%, lignin 18% and alkali soluble substances 17%. The mechanical properties of the mudar (Milkweed) bark fibers are tensile strength 381 MPa, strain at break 2.1% and Young's modulus 9.7GPa. Milkweed fiber is extracted from the Calotropis procera, it is a valuable plant that is easy to grow in dry and arid climate, requires minimum water and can be harvested for fiber twice a year. The bark fibers are long, with a thin wall relative to their diameter, and are therefore lightweight. Fiber is obtained from the stem husk of the plant and the inner bark was very tough and not suitable for extracting fibers. The members of this family are found in the tropical regions of Central and South America. In India, it is largely found in Punjab, Karnataka, Uttar Pradesh, Tamil Nadu and Andhra Pradesh. The milkweed has a low Density of about 0.90g/cm³. In general, fibers have enough potential for replacing or supplementing other fibrous raw materials as reinforcing agent [4].

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The cross-sectional shape, the density and tensile properties of the vakka, date and bamboo fibers fibers, along with established fibers like sisal, banana, coconut and palm were determined experimentally under similar conditions and compared [5]. The fibers introduced in the study could be used as an effective reinforcement for making composites, which have an added advantage of being lightweight. The alkali treatment on hemp fiber improved their suitability for reinforcements in composite materials [6]. 5% NaOH treatment to the fibers led to the improvements in tensile strength, Young's modulus, fiber separation, crystallinity index, lignin reduction and thermal stability. Lantana camara [7] fiber reinforced epoxy composite showed increase in tensile and flexural strength with increase in fiber content up to 30%. But moisture uptake increases with fiber loading due to increased voids and cellulose content and the moisture absorption reduced the tensile and flexural strength of composites. The study on the effect of alkali treatment on the banana fiber and its polyurethane reinforced composite [8] included the treatment of banana fibers with 10 % wt of NaOH, prediction of critical fiber length, tensile strength of the fiber and composite shows that alkali treatment improves the interfacial adhesion between fiber and matrix which in turn increases the tensile strength of the composite.

The untreated coconut coir fibers reinforced epoxy composites showed the tensile strength 13.05 MPa, tensile modulus 2.064GPa, flexural strength 35.42 MPa and it has been concluded that the poor interfacial bonding is responsible for low mechanical properties [9]. The study on the flexural properties of unidirectional long kenaf fibre reinforced epoxy composites revealed that reinforcement of epoxy with treated kenaf fibres increased the flexural strength of the composite by about 36%, while, untreated fibres introduced 20% improvement. This was mainly due to the high improvement of the chemical treatment (NaOH) on the interfacial adhesion of the fibres and the porosity of the composites which prevented the debonding, detachments or pull out of fibres. For untreated KFRE, the fracture mechanisms were debonding, tearing, detachments and pull out of fibres. The developed composite exhibited superior properties compared to the previous composites based on natural and synthetic fibers [10]. The review reports on the natural fibers are one of the potential low-cost, environmentally friendly materials that can be an indispensable component of polymer composite applications. Different kinds of natural fibers, due to their biorenewable nature and inherent eco-friendly characteristics, offer a number of advantages over synthetic fibers such as glass fibers, aramid fibers and carbon fibers. The effective utilization of different kinds of such natural fibers was discussed. Recently, in Europe some natural fibers are being used as one of the components in industrial applications and their use as green reinforcement in polymers has proved encouraging. The structural aspects and properties of various natural fiber polymer matrices and the polymer composites appropriate knowledge might be used in the near future for the commercialization of polymer composite products for an assortment of applications [11]. The study on effect of alkali treatment on the mechanical characteristics and interfacial adhesion of the fibers in a abaca fiber/ epoxy composite system showed that 5 wt. % NaOH treatment on abaca fibers increased crystallinity, tensile strength and Young's modulus compared to untreated fibers and also improved interfacial shear strength with an epoxy. Stronger alkali treatments negatively impacted fiber stiffness and suitability for composite applications. The mild alkali treatments are highly beneficial for the manufacture of abaca fiber-reinforced polymer composites [12].

It is understood from the literature study that lot of research on natural fiber reinforced polymer composites have been carried out but no research on Milkweed bast fiber reinforced epoxy composites has been done. This gap has triggered the scope for the present study which demonstrates raw and alkali treated Milkweed bast fiber and its potentiality for reinforcements in composites. The mechanical behavior of milkweed-epoxy composites is studied. The composite specimens with various fiber weight proportions are fabricated and the mechanical properties are investigated. Based on the outcome, the application products are suggested to explore the significance of this natural fiber to the composite materials field. Fig. 1 shows Milkweed plant.

Fig. 1 Milkweed Plant

II. METHOD & MATERIAL

1. Milkweed Fiber Extraction

The stems of milkweed plant are collected and dried under sunlight for 2-3 days. After drying, stems are dipped in water for 2-3 hours. Dipped stems are taken out and fiber is extracted by manual decorticating method as shown in Fig. 2(a). Extracted milkweed fiber is as shown in Fig. 2(b). The fibers have good length, strength, uniformity and fineness.

Fig. 2 (a) Fiber Extraction & (b) Extracted Fiber

2. Alkali treatment and mechanical testing of Milkweed fiber

Alkali treatment is the most widely accepted economical chemical method being adopted in surface treatment of natural fibers. The alkali treatment helps in providing roughness to the surface of fibers by removing unwanted amount of wax and oils covering the external surface. This is possible as alkaline treatment results in disruption of hydrogen bonding in the fiber network structure, thereby providing better mechanical interlocking and increased amount of cellulose exposed to the fiber surface. The alkali treatment improves the adhesive characteristics of fiber surface by removing hemicelluloses and lignin.

In the present work initially fibres are grouped into bundles of 60 fibres. Totally 16 groups of fibres are used for alkali treatment. Four different concentration solution of NaOH of strength 5%, 10%, 15% and 20% is prepared in distilled water. The bundles of fibre are immersed in each solution for 30, 60, 90 and 120 minutes. The fibre bundles are washed in tap water to clean the fibres and then in distilled water to remove the traces of NaOH, then the fibre bundles are dried.

The mechanical testing was done at PSGiTech, Coimbatore by taking sample size of 10 for each trail i.e., 10 individual fibers were considered and mean of the result was considered for each trial. Mechanical testing results are tabulated as shown in Table 1. The untreated fiber is also tested for mechanical properties and maximum tensile strength was found to be 294.30MPa.

Among all the conditions, the maximum stress for the alkali treated fibres was found to be 364.60MPa for 5% NaOH concentrated solution and 30 minutes. Using this optimum condition the fibres were treated and used for fabrication.

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Table 1 Tensile strength of fiber for different duration of soaking time and concentration in NaOH.

NaOH Conc.	Time (Minutes)			
	30	60	90	120
5%	364.60 MPa	330.97 MPa	276.10 MPa	250.44 MPa
10%	304.42 MPa	222.123 MPa	182.30 MPa	244.24 MPa
15%	229.20 MPa	238.05 MPa	285.84 MPa	304.24 MPa
20%	261.06 MPa	240.70 MPa	238.05 MPa	210.62 MPa

3. Chemical composition test of Milkweed fiber

Chemical composition test for untreated and alkali treated fiber were carried out at SITRA Chemical laboratory, Coimbatore and the test results are tabulated as shown in Table 2.

Table 2 Chemical composition test results

Fiber Chemical Composition	Untreated	Alkali treated
Cellulose Content, %	81.01	86.21
Lignin Content, %	10.77	5.71
Wax Content, %	0.49	0.27
Ash Content (on dry basis), %	2.18	1.56
Moisture Content, %	6.14	5.36
Density, g/cc	1.34	1.32

It is evident from the results that there is a decrease in lignin, wax, ash and moisture content in treated fibers compared to untreated fibers. The density of the treated fiber is also found to be decreased after alkali treatment.

4. Fabrication of composites

The composite plates are fabricated by employing the traditional hand layup technique. This is a very popular method of composite fabrication, limited by its ability to produce simple shapes. The chopped milkweed fibers of 5mm length are mixed with the epoxy resin and hardener to obtain various weight ratio of the reinforcement in the composite as per the experimental planning. The materials used for fabrication are L-12 Epoxy resin, K6 Hardener, Milkweed fiber, Glass mold, Teflon cloth, Releasing sheets and Load.

Epoxy resin is one of the matrix materials and it takes binding action between the fibers. Epoxy resin is formed out of chemical reaction between bisphenol and epichlorohydrin. Epoxy or Polyepoxide is a thermosetting epoxide polymer that cures when mixed with a catalyzing agent or "hardener". It has excellent adhesion property with great strength, toughness and resilience, excellent resistance to chemical attack and to moisture, outstanding electrical insulating properties with negligible shrinkage. Other epoxy resins for bonding, casting, tooling, pattern making, surface coating, laminating and concrete repairs are available. After pouring the epoxy into the beaker, hardener is added in the ratio of 10:1 and milkweed fibers of measured quantity are evenly mixed simultaneously. Glass sheet was used to build the mould having 20cm×15cm×0.3cm mould cavity. Teflon cloth is used to prevent the sticking of epoxy with glass and it helps in easy removal of model from the mold. The mold surface is completely covered with the Teflon cloth evenly by eliminating the air bubbles to get the smooth surface. The mixture was poured slowly into the mould cavity. Releasing sheet is placed over the filled mold and another glass plate is placed on it. Releasing sheet is used to prevent the sticking of upper surface of the composite with glass. After placing of releasing sheet and glass plate over the cavity, the load up to 15kg to 20kg is placed above it and it is left for around 24 hours for curing. Soon after curing the fabricated composite plate is taken out of the mould cavity by preheating of the mould and lifting the composite plate by sharp edge screw driver from the corner of the mould cavity. Fig. 3(a) shows the Teflon cloth covered Glass mold and Fig. 3(b) shows the fabricated composite plate. The composite plates of 5%, 10%, 15% and 20% milkweed fiber reinforcement were fabricated along with the neat epoxy plate. The test specimens are cut out from the fabricated composite plate as per the ASTM standards for mechanical testing. Average of three trials was considered in each individual test for each composition.

Fig. 3 (a) Glass mold (b) Composite plate

III. RESULTS AND DISCUSSIOINS

1. Tensile Test

The Tensile Test was carried out in CIPET, Mysore. For tensile tests the specimens are cut into the ASTM D638 standard of machine specification. Tests were carried out using universal testing machine. The test results were plotted for tensile stress versus specimen composition as shown in Fig. 4.

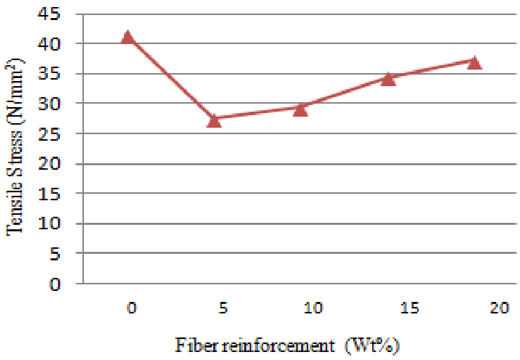

Fig. 4 Tensile test results of composites

Table 2 shows the tensile modulus and elongation at yield. Tensile modulus increased with fiber loading and corresponding to 20% fiber loading it showed higher value than the tensile modulus of neat epoxy specimen. The % of elongation at yield increased with the fiber loading, elongation was higher at 15% and 20% fiber loading compared to elongation of the neat epoxy. This trend can be related to the uniform fiber distribution and binding of the fibers within epoxy matrix at higher fiber loading.

Table 2 Modulus and elongation of composites

Fiber reinforcement (wt %)	Tensile Modulus (MPa)	Elongation at yield (%)
0	1456.57	2.13
5	1382.91	1.86
10	1412.53	1.97
15	1452.22	2.32
20	1474.31	2.61

2. Flexural Test

The Flexural Test is carried out in CIPET, Mysore. For Flexural tests the specimens were cut into the ASTM D790 standard of machine specification .Tests were carried out using flexural testing machine with 3 point loading. The test results were plotted for Flexural stress versus specimen composition as shown in Fig. 5.

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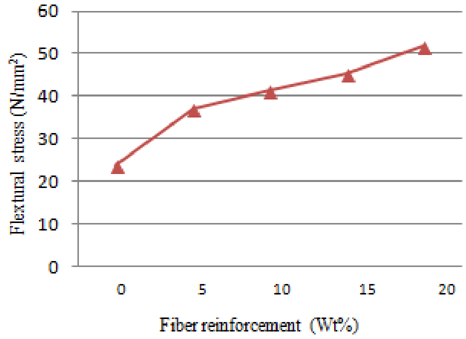

Fig. 5 Flexural test results of composites

Table 3 shows the flexural modulus of the fabricated specimens. The flexural modulus increased with the fiber loading and higher compared to neat epoxy specimen.

Table 3 Flexural modulus of composites

Fiber reinforcement (wt %)	Flexural Modulus (MPa)
0	3570.21
5	3906.51
10	4178.63
15	4293.72
20	5214.54

3. Impact Test

The impact Test are Carried out in CIPET, Mysore as per the ASTM Standard. Impact test specimens were cut into the ASTM D256 standard of machine specification. Tests were carried out using impact testing machine with one end is free and other end is fixed. The test results were plotted for Izode impact versus specimen composition as shown in Fig. 6.

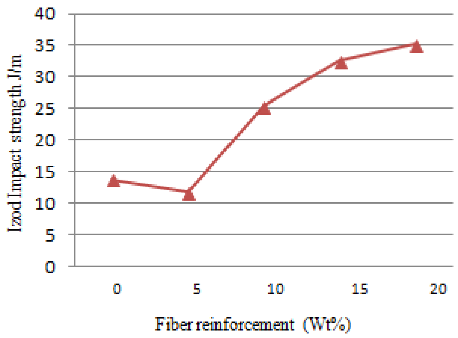

Fig. 6 Impact test results of composites

4. Hardness Test

The hardness test was carried out in CIPET, Mysore as per the ASTM D-2240 Standard. Hardness test specimens were cut into the ASTM standard of machine specification. Tests were carried out using hardness testing machine. The test results were plotted for Shore D hardness versus specimen composition as shown in Fig. 7.

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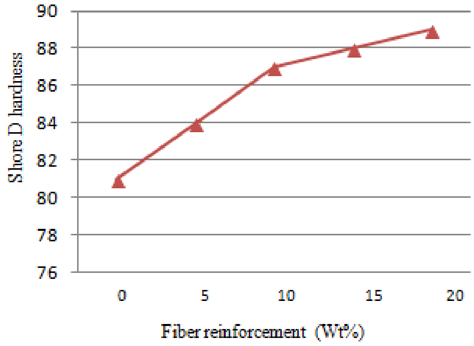

Fig. 7 Hardness test rersuls of composites

5. Density Test

The density test was carried out in CIPET, Mysore as per the ASTM standard. Density tests specimens were cut into the ASTM Standard of machine specification. The test results were plotted for density versus specimen composition as shown in Fig. 8.

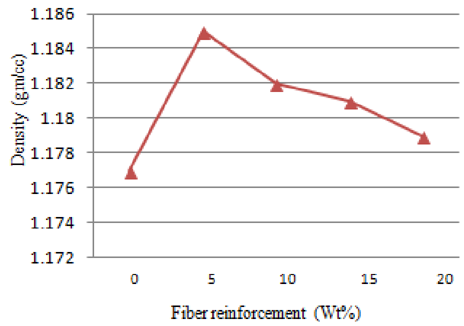

Fig. 8 Density test results of composites

IV. CONCLUSION

In this study, composites were fabricated using Milkweed fibers with varying fiber loading. The fiber surface treatment was done using 5% NaOH concentrated solution for a time duration of 30 minutes which was found to impart maximum tensile strength of 364.60MPa which is higher than the tensile strength of untreated milkweed fiber having maximum tensile strength of 294.30MPa. The surface treatment was found to be beneficial for the fiber which increased cellulose content and decreased the fiber density there by increased fiber fineness.

The tensile strength of the composites increased with increase in the fiber loading but lesser compared to the neat epoxy. The maximum tensile stress was 37.12N/mm^2 at 20% of fiber loading which is less as compared to tensile strength of neat epoxy which was 41.47N/mm^2. The flexural strength of the composites increased with increase in the fiber loading compared to the neat epoxy. The maximum flexural stress was 51.18N/mm^2 at 20% of fiber loading where as flexural strength of neat epoxy is 24.31N/mm^2. The Izode Impact strength of the composites decreased at 5% fiber loading but increased with increase in the fiber loading compared to the neat epoxy. The maximum Izode Impact strength was 35.01J/m at 20% of fiber loading where as Izode Impact strength of neat epoxy is 13.77J/m. The hardness of the composites increased with fiber loading compared to the neat epoxy. The maximum Shore D hardness is 87 at 20% of fiber loading where as for neat epoxy it is 81. The density of the composites increased at 5% fiber loading and decreased on fiber loading but higher compared to the neat epoxy which is having density of 1.177gm/cc.

The resulting properties reveal that composites with good strength could be successfully developed by using Milkweed fiber as reinforcement in epoxy matrix. In addition, Milkweed fiber is a valuable renewable natural resource for composite production and could be utilized successfully as a substitute for wood in composite production. The milkweed fiber reinforced composites can be used in the applications where flexural and impact strength is critical.

The present work is only a small attempt to study the mechanical behavior of some specific composition of milkweed fiber reinforcement in epoxy polymer matrix. The composition of fiber can be varied and optimized for better results. There is large scope for future study, considering different weight fractions or volume fractions, hybridizing with other synthetic fibers. The similar experiments can be carried by changing the matrix material, chemically treating the fiber and also by hybridization with synthetic fibers like, glass fiber and carbon fiber.

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