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A Case Study of Water Absorption Behaviour of Natural Fiber

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***Abstract*: In this paper, we studied about the local existing low-cost fibers and to investigate their possibility of reinforcement intensions. And also, the present work has been under taken to develop a polymer matrix composite using Luffa fiber and to study its moisture absorption behavior.**

***Keywords*: Reinforcement, Luffa fiber, composites, thickness swelling.**

1. Introduction

A. Back ground

Composites are mixture of two or more materials such as reinforced plastics, metals, or ceramics. The reinforcements may be in the form of fibers, particles, whiskers or lamellae and are embedded in a suitable matrix, thereby providing a material that contains the most useful properties of the constituents. High structural strength, glass fiber reinforced plastics were developed in the early 1940's and the application of reinforced plastics composites, the glass fiber provides strength and stiffness while the plastic matrix provides the temperature capabilities of the composite. Initially the glass fibers were incorporated in a polyester matrix which could withstand temperature up to 200^0C. They were applied in car bodies, appliances, boats etc., because of their light weight and mitigate of production. Intricate composites parts can be made by injection moulding. Polymer matrices are usually thermosets such as epoxies. Later, resins which can withstand high temperatures, of the order of 300^0C were developed such as polyamides. Other thermo setting resins include benzocylobutene- bismaleimides. Advanced composites are manufactured by using the above polymers with reinforcements of stronger. Fibers such as aramid and carbon. As a result, advanced composites are finding increasing applications in aircraft, automotive industry, etc. In order to reduce the manufacturing time, thermoplastics polymers such as polyether ether ketone (PEEK) have been developed. The plastic requires only a short revelation to heat to soften the plastics, thereby allowing faster processing of the composite. The temperature range of application of metal matrix composites is lower than that of ceramic matrix composites. Ceramic matrices such as zirconia, alumina, silicon nitride, silicon carbide, mullet etc. can be reinforced with ceramic continuous fibers, whiskers or particulates. Carbon-carbon composites are a ceramic composite which can retained its strength at temperatures up to 2500^0C and is applied as a critical component in aerospace. The study of composites materials is a multifaceted memorandum as it is difficult for any individual to grasp the compound behavior of many of the current composites. This field provides lot of analytical problems for experimental schedules, theoreticians for research workers and new defiance for designers.

B. Composite materials

A composite material is composed of reinforcement (fibers, flakes, particles and fillers) implanted in a matrix such as polymers, metals, or ceramics. The function of matrix is to hold the reinforcement to form the craved shape while the reinforcement improvement the whole mechanical properties of the matrix. The new combined material possesses better strength than each individual material in a system, when designed correctly. As stated by Jarvis [1], Composites are such a universal material which can provide such properties that are not possible to obtain from any distinct material. Composites possess cohesive structures brought up by physically amalgamating two or more suited materials, but different in composition and characteristics and occasionally in configuration. Kelly evidently [2] emphasizes that the composites should not be considered as just combination of two different materials. In wider sense; the amalgamation has its particular characteristic properties. In relations of strength, heat resistant or specific other advisable quality, it is far better than the components taken individually or fundamentally different from both of them. Bergeson [3] defines as "The composites are amalgamated materials which differ from alloys by the fact that the individual components in composites preserve their characteristics but are combined in such a way so as to take advantage of their features only and not of their limitations", in order to obtain a much better material. Van Suchetclan [4], describes composite materials as diverse materials which consist of two or more solid states that are in constricted interaction with each other. He also stated that composites can be also contemplated as homogeneous material on a microscopic level in a way that whichever part of it is separated will have the physical property same as the composite.

C. Natural fiber composites

The cost-effective options to synthetic fiber reinforced composites and the interesting studies of plant or natural fiber inspires the researchers to make advances in the field of composites. Ease in access and built-up simplicity of natural fiber have convinced these researchers to try natural fibers which are available locally and to study their practicability of reinforcement motives. These are also studied to have the information that up to what limit they can fulfil the desired specifications and properties for various uses. Natural fiber appears as a good renewable and biodegradable substitute to most of the synthetic fiber such as glass fiber. Vegetables, animal, mineral fibers etc. fall under the area of natural fiber. Generally, it is referred as wood and agro based fiber, leaf, stem and seed fibers in the composite engineering. A natural fiber frequently contributes to the structural presentation of plant and they can deliver substantial reinforcement, when used in the production of plastics composites. Accordingly, vast studies on construction and properties of polymer matrix composite (PMC) substituting the synthetic fiber with natural fiber like Jute, Pineapple, Sisal, Kenaf, Bamboo, luffa, and Bagasse were executed. Above natural fibers have numerous advantages over the glass fiber or carbon fiber such as renewable, low cost, lightweight, high specific mechanical performance.

Fig. 1. Natural fiber

D. Luffa as a natural fiber

Numbers of potential natural resources are there, which India has in abundance. Most of which comes from the forest and agriculture. Luffa, locally called as ‘Sponge-gourds’ is that natural resource whose capability as fiber reinforcement in polymer composite has not been explored to date. The fibrous cords are liable in a multidirectional array resulting in a natural mat in ligneous netting system possess by ‘Sponge gourd’. It comprises 62% cellulose, 20% hemicellulose and 11.2% lignin [1]. The sponge-gourd (Luffa) plant with fruit which belongs to the Cucurbitaceae family is shown in Fig.

2. Review of literature

The moisture uptake of composites comprising natural fibers has some unfavorable causes on their properties and hence disturbs their long-term presentation. In view of the sternness of moisture absorption and its consequences on composite properties, a number of efforts have already been made by several researchers to address this issue. Jena et al. [5] studied the water absorption behavior of bamboo-epoxy composite filled with chemosphere. Water absorption of bamboo fiber increases with time of immersion, attaining a saturation point after which it remains constant. She observed that the saturation point was different for two different environmental conditions. For distilled water it was 216 h whereas for saline water it was 168 h. Joseph et al. [6] investigated the environmental effects on sisal fiber reinforced composites. Absorption of water was found to be increased with the fiber content and then settled off at longer period of time. In order to overcome this problem, the fibers were treated chemically and the chemically treated fibers showed a decrease in water absorption because of the enhanced interfacial bonding. As the temperature stimulates the diffusion procedure, it was found that the water absorption of the composite increases with the temperature. Plasticization effect of water was the reason to decrease the tensile properties of the composite. Obohet al. [7] have reported the potentialities of Luffa crop that is virtually found around the world. Regions such as medicine, agriculture, science, biotechnology and engineering were discussed. Recent major improvements and discoveries were considered. They conclude that in the context of the morpho synthesis, the capability of replication of the luffa sponge unties the chances of the use of biodiversity in obtaining new materials. This emerging cash crop will expand the economies of many nations in the nearest future because of its numerous potentials. Yoldas Seki et al. [8] carried out report of Luffa by scanning electron microscopy (SEM) analysis. The contents of hemicellulose, lignin and cellulose in Luffa were determined. They subject luffa-reinforced polyester composite to water aging in a steam of seawater containing 5% NaCl for 170 hrs. at 500C. They found that flexural strength, tensile strength, tensile elongation and interlaminar shear strength at break values was decreased by 28%, 24%, 45%, and 31%, respectively, after the process of aging.

3. Experimental analysis

A. Preparation of luffa fiber mats

Dried Luffa was collected locally. These fibers were then treated with water for 24 hrs. in order to remove wax, lignin and oil from the external surface of luffa fiber and then dried at room temperature. After these the fibers were cut with appropriate dimensions (140×100 mm) and then these fibers were kept between two wooden boards followed by pressing it into the bench vice to straighten the fibers.

B. Epoxy resin

The epoxy resin used in this examination is Araldite LY-556 which chemically belongs to epoxide family. Its common name is Bisphenol-A-Diglycidyl-Ether. The hardener with IUPAC name NNO-bis (2aminoethylethane-1,2diamin) has been used with the epoxy designated as HY 951.

C. Composite preparation

Initially, wooden moulds with dimensions of 140 x 100 mm2 were prepared for the fabrication. For different number a layer of fiber, epoxy resin and hardener (ratio of 10:1 by weight) with a calculated amount was mixed thoroughly in a glass jar. Fig. 2, illustrates the mould used to construct the composite. Mould release sheet was put over the glass plate and a mould release spray was sprayed over the inner surface of the mould for quick and easy removal of composite. After keeping the mould on a ply board a thin layer of the mixture was poured. Then the fiber lamina was distributed on the mixture. Then again resin was applied over the fiber laminate. The remaining mixture was then poured into the mould. Precaution was taken to prevent the air bubbles formation. Then from the top pressure was applied and the mould was kept at room temperature for 24 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 24 hrs the samples were taken out of the mould.

Following figures shows the photograph of the composite specimen cut for further experiment.

Fig. 2. Composite preparation

D. *Study of environmental effect*

To study the effect of environmental conditions on performance of Luffa fiber epoxy composite, the composite sample with of Luffa cylinderica fibers were subjected to various environments such as:

- Saline
- Distil

E. *Moisture absorption test*

Moisture absorption and thickness swelling tests were conducted. Four specimens for different layers (Single, Double and Triple) were cut with dimensions of 140mm x 15mm (length x width) and the experiment was performed using test samples. The specimens prior to testing were dried in an oven at approximate 80^0 C and then were allowed to cool to room temperature and kept in a desiccator. The weight of the samples was taken before subjected to steam, saline water and distil water environments. After expose for 24hr, the specimens were taken out from the moist environment and all surface moisture was removed with a clean dry cloth or tissue paper. The specimens were reweighed to the nearest 0.001 mg within 1 min. of removing them from the environment chamber. The specimens were weighed regularly from 2-10 hrs. with a gap of 2hrs of exposure. The moisture absorption was calculated by the weight difference. The percentage weight gain of the samples was measured at different time intervals by using the following equation:

$$\%Mt = \frac{(W_t - W_0) \times 100}{W_0}$$

Where 'W_0' and 'W_t' denote the oven-dry weight and weight after time 't', respectively.

Equilibrium Moisture Content (EMC) of the sample is the moisture content when the periodic

weight change of the sample was less than 0.1% and thus the equilibrium state was assumed to be reached.

The thickness swelling (TS) was determined by using the following equation:

$$TS(t) = \frac{(H_t - H_0) \times 100}{H_0}$$

Where, 'H_t' and 'H_0' are the composite thickness after and before the water immersion respectively.

4. Results and discussion

The results of Luffa fiber composite samples exposed to different environments are shown in Tables.

A. *Moisture absorption behavior*

It shows the percentage of moisture absorption characteristics of samples of composite fiber exposed to Saline water and Distil environment with time. It is quite obvious from the table that as the fiber content increases, the initial rate of moisture absorption and the maximum moisture absorption for both the environment increases. Moisture absorption is maximum for three layered composites. It is known that, the factors like adhesion between fiber and matrix, porosity content and the lumen are responsible for the moisture absorption behavior of the natural fiber composites. But in this case the hydrophilicity of Luffa fiber, in addition to poor adhesion between fiber-matrix and voids content might have affect the moisture uptake characteristics of the composite. Environmental conditions also play a significant role in moisture absorption process. In Distil Water environment moisture absorption is maximum as compare to saline water environment. The rate of absorption in case of saline water is low as compared to steam. This happens because of the gathering of NaCl ions in the fiber's surface immersed in saline

Table 1

Variation of weight gain and thickness swelling of Luffa fiber epoxy composite of single layer with immersion time expose at distil environment.				
Immersion Time 't' (hrs.)	Weight of the Sample (g)	Percentage of weight gain (%M)	Thickness at time 't' H(t)	Thickness Swelling TS (t)
0	12.761	0	0.59	0
2	12.986	1.763184703	0.591	0.16949152
4	13.038	2.170676279	0.592	0.33898305
6	13.063	2.366585691	0.593	0.50847457
8	13.136	2.938641172	0.594	0.67796610
10	13.213	3.54204216	0.595	0.84745762

Variation of weight gain and thickness swelling of Luffa fiber epoxy composite of double layer with immersion time expose at distil environment.				
Immersion Time 't' (hrs.)	Weight of the Sample (g)	Percentage of weight gain (%M)	Thickness In cm H(t)	Thickness Swelling TS (t)
0	15.504	0	0.707	0
2	15.954	2.90247678	0.709	0.282885431
4	16.123	3.99251806	0.71	0.424328147
6	16.421	5.914602683	0.713	0.848656294
8	16.652	7.404540764	0.715	1.131541726
10	16.669	7.514189886	0.717	1.414427157

Variation of weight gain and thickness swelling of Luffa fiber epoxy composite of triple layer with immersion time expose at distil environment.				
Immersion Time 't' (hrs.)	Weight of the Sample (g)	Percentage of weight gain (%M)	Thickness In cm H(t)	Thickness Swelling TS (t)
0	16.974	0	1.125	0
2	18.166	7.02250501	1.128	0.266666667
4	18.414	8.4835631	1.132	0.622222222
6	18.831	10.9402616	1.136	0.977777778
8	19.162	12.8903028	1.14	1.333333333
10	19.284	13.6090491	1.143	1.6

Variation of weight gain and thickness swelling of Luffa fiber epoxy composite of single layer with immersion time expose at saline				
Immersion Time 't' (hrs.)	Weight of the Sample (g)	Percentage of weight gain (%M)	Thickness In cm H(t)	Thickness Swelling TS (t)
0	11.836	0	0.55	0
2	12.014	1.503886448	0.551	0.181818182
4	12.18	2.906387293	0.552	0.363636364
6	12.291	3.844204123	0.553	0.545454545
8	12.368	4.494761744	0.554	0.727272727
10	12.532	5.880364988	0.555	0.909090909

Variation of weight gain and thickness swelling of Luffa fiber epoxy composite of double layer with immersion time expose at saline environment.				
Immersion Time 't' (hrs.)	Weight of the Sample (g)	Percentage of weight gain (%M)	Thickness at time 't' H(t)	Thickness Swelling TS (t)
0	15.665	0	0.769	0
2	15.821	0.995850622	0.771	0.26007802
4	16.246	3.708905203	0.773	0.52015604
6	16.521	5.464411108	0.775	0.78023407
8	16.825	7.40504309	0.777	1.04031209
10	16.993	8.477497606	0.779	1.30039011

Variation of weight gain and thickness swelling of Luffa fiber epoxy composite of triple layer with immersion time expose at saline environment.				
Immersion Time 't' (hrs.)	Weight of the Sample (g)	Percentage of weight gain (%M)	Thickness In cm H(t)	Thickness Swelling TS (t)
0	17.75	0	1.113	0
2	18.324	3.233802817	1.117	0.359389039
4	18.925	6.61971831	1.121	0.718778077
6	19.363	9.087323944	1.124	0.988319856
8	19.724	11.12112676	1.128	1.347708895
10	19.947	12.37746479	1.131	1.617250674

water, which increases with time and delays moisture diffusion.

B. Applications

- *Automobile industry:* For inner and outer parts fiber reinforced plastics are used. These are used in industries because of their advantages over the glass fiber reinforced composites such as cheaper, environment friendly, etc. By these fibers' cars according to End-of-Life directive can be developed as the resulting products from these composites can be re-used and do not have to be land filled unlike glass fiber. Because of their softness and non-harsh behavior unlike glass fibers they are used in interior automotive uses and are having advantages of not injuring the passengers.
- *Packaging industry:* In these industries these are used for light weight pallets. Weight reduction is the chief reason for using composite material in place of wood, which saves fuel during transportation
- *Consumer products:* Natural fiber can be used for any injection moulded product. Reduction of plastic use, flame retardancy and re-use. Examples are household appliances like cell phones, refrigerators and computers. They are less vulnerable to fire due to the fiber structure of composite. Also, the high fiber loads results in major material cost reduction.

- *Building and construction industry:* In these they are used for roofing and instance profiles. Cost reduction, re-use and flame retardancy are the advantages.

5. Conclusion

Based on experimental results, this study has led to the following conclusions:

- The Luffa fiber can successfully be used as reinforcing agent to fabricate composite by suitably bonding with epoxy resin.
- The moisture uptake and thickness swelling values increases with increase in fiber loading. Both values are found to be higher in saline environment than in distil water environments. However, these values are considerably reduced with chemical treatments of the fiber.

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