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Development of Natural Fiber Composites and its Analysis

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Abstract – *In the present scenario of fast growing world, the problem of depleting resources is a major concern for mankind. Also the extraction techniques of some materials lead to environmental pollution and thus the need for alternative material development has taken a major leap in the recent years. This has led to the development of composite materials and especially natural fiber composite materials. The natural fibers provide added advantage over their synthetic counterparts in terms of durability as well as sustainability. The present paper focuses on the development of banana fiber and jute fiber composites, their analysis and also a brief comparison. An effort is also made to suggest a suitable replacement of the developed material wherever possible.*

Key Words: composite, strength, natural fibres, analysis, sustainability, banana, jute, etc.

1. INTRODUCTION

The world today is fast growing and the conventional materials which are in use today are seeing a growing trend of replacement with newer materials. This is because for some materials the strength to weight ratio is a concern, while the extraction of other leads to pollution. The world is now looking for sustainable materials which not only provide the adequate properties but are also beneficial to the environment. Here the fiber reinforced composite comes into picture.

A composite material consists of two or more components with different physical and chemical properties, which when combined together produces a material with altogether different properties than the individual materials. The properties thus obtained are better and favorable. The fibers used in the material can be of two types; the most commonly used are the synthetic fibers like glass, carbon and the natural fibers include bamboo, banana, coir, jute, etc. Synthetic fibers are artificial or manmade fibers which are technically non-biodegradable. They have excellent mechanical properties. The best example is the carbon fiber composite which has a wide range of applications in aircraft industries, automobile industry, etc.

Natural fibers are biodegradable fibers as they are obtained from nature. This makes them more promising as compared to synthetic fibers. The major concern is the strength. Research is underway in finding out a good natural fiber composite with excellent mechanical and chemical properties.

2. LITERATURE SURVEY

Many researchers have worked in the area of banana and jute fiber composites. Ramesh et al. prepared composites using hand layup process which was followed by applying pressure using compression molding. Tensile, flexural and impact test was carried on 3 samples with different volume fractions of 40, 50 and 60% each. The tensile strength was maximum for 50% volume fraction which was 112.58 MPa and a maximum flexural strength of 76.53 MPa was also seen for this sample [1]. Venkateshwaran et al. in their research work concluded that due to low density, high tensile strength, high tensile modulus, and low elongation of break of banana fibers, composites based on banana fiber have a very good potential use in the various sectors like construction, automotive and machinery [2].

Dhakal Saurab et al. in their research work fabricated short raw banana fiber polyester composite. Randomly oriented banana fiber reinforced composite with a volume fraction of 5%, 10%, 15%, 17.5% and 20% were fabricated using hot compression molding method. Thickness of specimen was taken as 3mm and 5mm. It was found that the 5mm fiber with a volume fraction of 20% showed the best results. A tensile strength of 23.04 MPa, flexural strength of 124.61 MPa and 147.15 J/m impact strength was seen as the maximum values for 5mm fibers with 20% volume fraction [3].

Kumar Sujeet et al. in his project work collected fibers from a local store and dried them for 8-10 hours in sunlight so that all the moisture content is lost. The dried fibers were cut into lengths of 5mm, 10mm and 15 mm. Epoxy resin was used as matrix. Hand layup process was used for the fabrication of the banana composite. He found that better mechanical properties was found for 10 mm fiber length with 15% fiber composition. He also concluded that fiber loading and length has a major effect on the mechanical properties of the composites like hardness, tensile strength, etc. [4].

Alavudeen et al. studied the effect of woven fabric and random orientation of banana fibers on the properties of the composites. Composites were prepared using two different weaving patterns, plain and twill-type. The plain type showed good tensile properties as compared to the twill counterpart [5].

Indra Reddy et al. studied the mechanical properties of jute, pineapple leaf fiber and glass fiber reinforced composite with polyester and epoxy resin matrix. The three fibers were taken in the ratio of 1:1:1 into polyester and epoxy resin. Fiber content in the composite was varied 18% to 42% by volume fraction and mechanical properties like tensile, flexural and impact tests were carried out. It was found that the fibers with epoxy matrix showed better results as compared to polyester matrix [6].

In the present project, development of banana and jute fiber random orientation composite was carried out. The fibers were extracted mechanically and a sheet of composite material was made with epoxy resin as a matrix.

3. DESIGN OF THE COMPOSITE

3.1 Fibers

The fibers are the most important part of the composite. We chose natural fibers due to their excellent sustainability with the environment and also they are eco-friendly. Banana fibers and jute fibers were used to prepare two different types of composite.

The fibers contain a large amount of cellulose as well as lignin content. For better strength, the lignin content of the fibers must be removed. Hence the fibers were treated in 0.1N NaOH solution. After treating the fibers were washed thoroughly under running water to remove all the NaOH content and then dried in sunlight for a day. This was to remove the moisture content of the fibers. Random orientation of fibers were used for the project. The fibers were cut to length according to required dimension. A length of 20 mm for fibers was chosen. We chose 20mm as the length of the fibers.

3.2 Matrix

Matrix is the part of the component which holds the fibers together. It also has the function of carrying the load along with the fibers. Epoxy is one of the most common matrix material used. The epoxy resin was purchased from a local store along with the hardener. The density of the matrix was found to be 1200 kg/mm^3. The quantity of epoxy as well as the hardener were measured according to the calculations. The same resin was used for both the composite structures.

3.2 Mold

A mold of 200mm*100mm*5mm was to be prepared for the composites. A volume fraction of 20 % for fibers was chosen for both the composites. The calculations for the amount of fiber and matrix are as follows:

For banana fibers:

Let,

V_t = Total volume of the mold
V_f = Volume of fibers required
V_m = Volume of matrix required
M_f = Mass of fibers required
M_m = Mass of total matrix required
x = volume fraction
ρ_f = density of fiber
ρ_m = density of matrix
V_t= 0.2x0.1x0.005= 10^{-4} m3
V_f = 0.2xVt= 10^{-4}x0.2 = 2x10^{-5} m3
ρ_f = 1350 kg/m^3
Mf = 1350x2x10^{-5} = 0.027 kg = 27 gm
ρ_m= 1200 kg/m^3
V_m = 0.8xV_t= 10-4x0.8 = 8x10^{-5} m^3
M_m = 1200x8x10^{-5} = 0.096 kg = 96 gm

Consider epoxy resin and hardener in the ratio 2:1, for banana fibers, mass of epoxy was taken 88 gm and mass of hardener was taken 44 gm respectively.

For jute fibers:

Let,

V_t = Total volume of the mold
V_f = Volume of fibers required
V_m = Volume of matrix required
M_f = Mass of fibers required
M_m = Mass of total matrix required
x = volume fraction
ρ_f = density of fiber
ρ_m = density of matrix
V_t = 0.2x0.1x0.005= 10^{-4} m^3
V_f = 0.2xV_t= 10^{-4}x0.2 = 2x10^{-5} m3
ρ_f = 1460 kg/m^3
M_f = 1460x2x10^{-5} = 0.029 kg = 29 gm
P_m = 1200 kg/m^3
V_m = 0.8xV_t = 10^{-4}x0.8 = 8x10^{-5} m^3
M_m = 1200x8x10^{-5} = 0.096 kg = 96 gm

Considering epoxy and hardener in the ratio of 2:1, for jute fibers, mass of epoxy was taken 64 gm and mass of hardener was taken 32 gm respectively.

The measured quantity of fibers, epoxy and hardener were taken in separate containers. A wooden mold of dimension 200*100*5 mm3 was prepared. The mixture of matrix and the fibers was made and was poured in the mold. A constant pressure of 600N was applied on top of the mold for compaction for approximately 3 hours before the load was removed. Then both the composites were placed in the sunlight for the whole day for good curing of the composites. The total volume was so chosen that a specimen for tensile test, flexural test and Izod impact test respectively would be easily cut from the mold. The specimen dimensions chosen were according to ASTM standards. The different standards for different tests are given in the Table 2 which are according to ASTM standards.

The composite sheet prepared for both the fibers were taken to the water jet machining workshop for the cutting of the specimens. The specimens were cut using abrasive water jet machining with a good accuracy.

The specimens of both the fibers namely, banana and jute were cut according to ASTM standards. Two sheets each of both the composites were prepared and the specimens were cut accordingly based on the tests to be performed.

Table -1: ASTM Standards used for various tests

SR NO.	TEST NAME	STANDARD
1	Tensile test	ASTM D-638
2	Flexural test	ASTM D-790
3	Izod impact test	ASTM D-290
4	Compression test	ASTM D-695

The specimens had a depth of approximately 5-7 mm range. This was because of manufacturing difficulties and not so proper compression techniques. The mold prepared are shown in the Figure 1 and 2 whereas the cut specimens after Water-jet cutting are shown in the Figure 3.

Fig -1: Prepared sheet for Jute composite

Fig -2: Prepared sheet for Banana composite

Fig -3: Specimens after Waterjet Cutting

4. RESULTS AND DISCUSSION

A total of three different types of tests were conducted on the composites, namely tensile strength test, Izod impact test and flexural test. The details of these tests are given below.

4.1 Tensile Test

The banana and jute fiber composite specimen were prepared with 20% volume fraction. The tensile test was conducted on the universal testing machine STS 248 according to ASTM D-638 standards. The nature of the curve obtained is shown in the Figures 4 and 5 for banana and jute composite respectively.

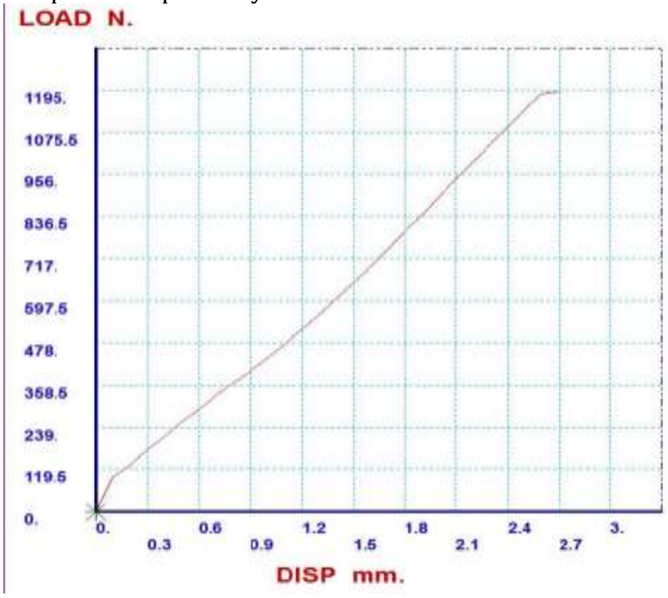

Fig -4: Load VS Displacement diagram during tensile test for Banana composite

Fig 5: Load VS Displacement diagram during tensile test for Jute Composite

It is seen from the graph that the ultimate tensile strength for jute composite was higher than that of banana composite for the same volume fraction of fiber. The tensile strength of banana fiber was found to be 11.720 MPa (sample1) and for jute fiber it was 20.64 MPa (sample2).

4.2 Flexural Test

The specimens for both the composites were cut according to ASTM D-390 standards. The test was conducted on STS 248.The load versus deformation graph for the banana and jute composite is shown in the Figure 6 and 7 respectively. It is seen that the Flexural strength for jute is less as compared to that of banana fiber composite. The flexural strength of banana composite was 33.297 MPa (sample1) and for jute it is 32.384 MPa (sample1). The difference was not much between the two results.

Fig 6: Load VS Deformation diagram during Flexural test for Banana Composite

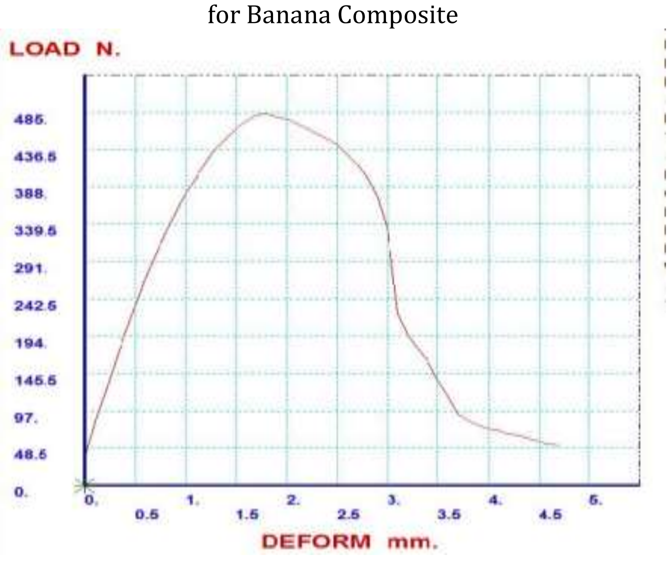

Fig 7: Load VS deformation diagram during Flexural test for Jute Composite

4.3 Izod Impact Test

To analyze the impact capacity of the samples and to see which material can absorb a more amount of sudden load, impact test was done on the specimens of both composites. The specimens were cut according to ASTM D-256 standards. The test was carried on Izod/Charpy impact tester of model 430. Here, the jute composite showed better results as compared to banana composite. The impact energy of jute was 5.36 KJ/m2 (sample1) and the impact energy of banana composite was 3.07 KJ/m2 (sample2).

4.3 Compression Test

Compressive strength of brittle material is more as compared to tensile strength, hence to analyze the strength of both the composites; compressive test was done on both, banana as well as jute composites. The specimens were cut according to ASTM D-695 standards. The tests were done on universal testing machine STS 248. The jute composite and banana composite showed similar results with jute being the better of them. It had a compressive strength of 178.49 MPa (sample2) while the banana composite had a compressive strength of 176.05 MPa (sample2).

5. ANALYSIS OF A CHAIR WITH BANANA COMPOSITE MATERIAL

As an application of banana composite that was manufactured, a detailed static structural analysis was done on a chair having box dimensions as 460*546*811 mm. the analysis was done on Ansys Workbench 14.5. A load of 800 N was applied on the chair. The results of the analysis are shown in the Figures 8, 9, 10 and 11.

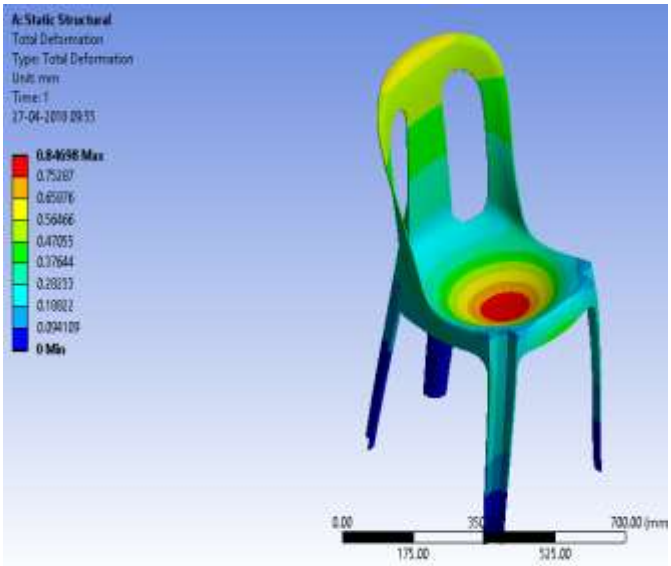

Fig 8: Total Deformation

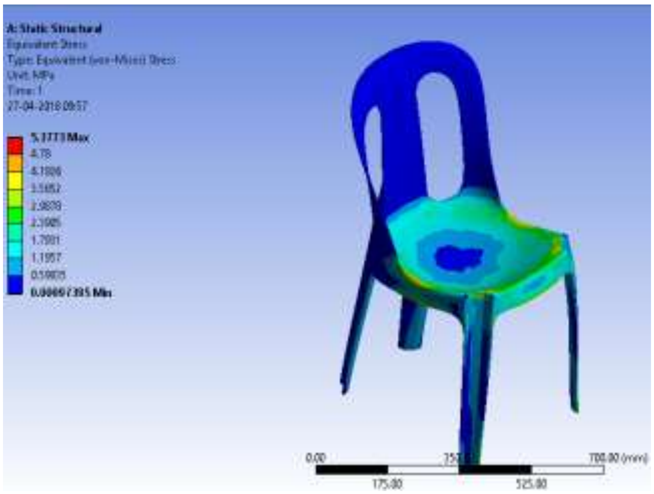

Fig 9: Equivalent Stress

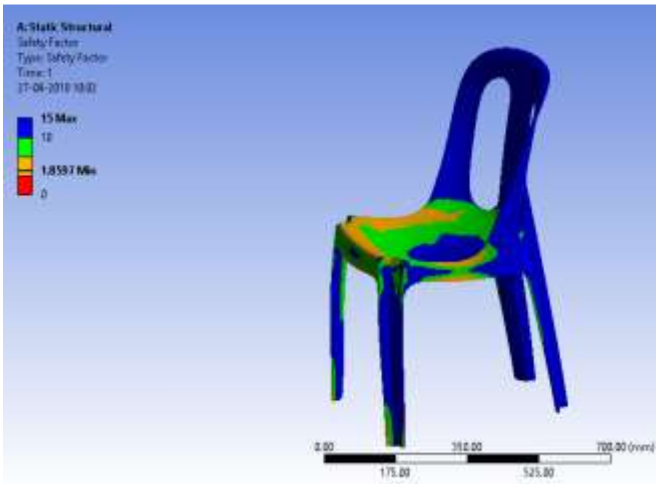

Fig 10: Maximum Principal Stress

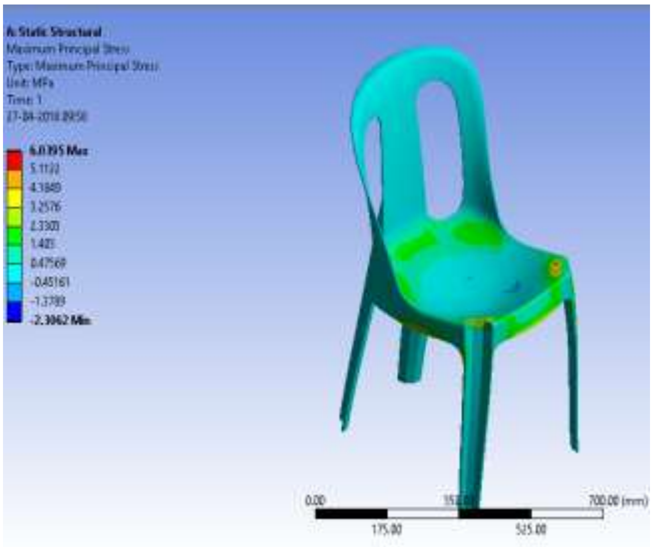

Fig 11: Safety Factor

6. CONCLUSION

From all the tests it was seen that the jute fiber composite had better mechanical properties as compared to banana fiber composites for the volume fraction of 20% and the fiber length of 20mm. The test results depend on the void factor too. There were a number of voids in the composite sheet that was prepared for both the fibers. These void act as stress concentrators and hence the strength results could have been much better if void would have been minimum. The fibers quality as well the type of epoxy affects the strength of the composite. Care should be taken that fibers are well treated so as to remove impurities and to increase the fiber strength.

From the results it is clear that the composites are better in handling compressive loads as compared to tensile loads. This is because voids act as a stress concentration factor in tension while there is a negligible effect of these voids at the time of compression.

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