

Comparative Study of Impact Properties of Coir & Aloe Vera Based Composites With GFRP

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Abstract

This study compares the use of Coir & Aloe vera fibre composites and that of GFRPs for use in bumpers in automotive applications. White Coir was chosen because of its excellent anti-weathering property and high strain to failure. A multi-fibre composite was devised by blending both Aloe vera and coir and weaving them to form a bi-directional mat. Other samples contained pure Coir and pure Aloe vera, both in randomly oriented mats and bi-directional mats. Before composite fabrication, the fibres were subjected to chemical modification using NaOH, to decrease water absorption. They were reinforced in a matrix of Polypropylene / Polyester. The fabricated natural fibre composite samples along with GFRPs were subject to impact testing by un-notched Charpy Impact test. SEM analysis was carried out on the fracture surfaces of impact samples.

Keywords: Bio composites, Aloe vera, Coir, GFRP, impact strength

Introduction

In recent years, the automobile industry has started focussing on alternatives to the conventional GFRP based products because of the growing environmental concerns related to recyclability and bio-degradability. With directives like the European Union's End of Life

Vehicle directive focussed on recycling and disposal of vehicles after their service life, according to which 85% of the total weight of the car should be recyclable for all cars produced after 2006 and 95% recyclability for cars being produced from 2015 onwards, car manufacturers are trying to replace GFRPs with Natural Fibre based composites.

The Natural fibre composites have certain inherent advantages over the glass fibre with respect to density, cost, processability, non-toxicity and bio-degradability; but it also has its drawbacks, namely, poor wettability, high moisture absorption and property variation from batch to batch.

Abdul Khalil et al (2006) analysed the structure and morphology of plant fibres and found that the coir fibres have the highest percentage of lignin which makes its fibre stiffer and tougher [1]. Dieter H. Meuller (2004) analysed the effect of the processing temperature on the impact properties of the composites [2]. Maya Jacob John and Rajesh D. Anand Jiwala correlated the structure of the cell wall in the plant fibre to the mechanical properties of the natural fibre based composite [3].

M.S. Sreekala et al (2000) in their work with Oil Palm fibre and Phenol Formaldehyde composites have showed the effect of chemical treatment on the mechanical properties of the natural fibre composite [4]. J. Rout et al (2001) have also shown that the amount of water absorption is greater in the case of un-treated samples when compared to alkali treated samples due to poor wettability and hydrophilic characteristics of the un-treated fibre [5]. M.N. Islam et al (2010) attributed the increase in water absorption in un-treated fibres due to the presence of micro-voids between the fibre and the matrix and the interface which result in large amount of water in-take [6].

Zhouhua Li et al (2002) showed that with increasing surface roughness of the fibre, the contact area available for bonding with the matrix increases leading to higher interface bond-strength and that the increased surface roughness enhances the friction at the fibre – matrix interface during fibre sliding [7]. (2000) Orksan showed that at lower interface strength fibre pull-out would be the more dominant mechanism resulting in greater absorption of impact energy [8]. Also, Ye et al (1998) showed that the composites with weaker interface have better impact strength when the direction of propagation of crack is perpendicular to the surface of the fibre / matrix interface [9].

J. Gazzan and A.K. Bledzki showed that in Jute – PP samples, at lower impact energies, the composite failure is by delamination and debonding whereas at high energies the dominant mechanism is fibre pull-out or fibre fracture [10]. Since jute has similar fibre characteristics compared to coir, the same mechanism applies to it too. P. Wambua et al (2003) show the dependence of the fibre volume fraction on the impact properties of Coir-PP composites, where they observed a moderate increase in the impact properties of the composites with increase from 30% to 40% fibre volume fraction and a sharp increase at 50% volume fraction. Also at 50%, the fibre surface showed a lot of serrated edges showing that it had absorbed a larger energy on impact [11].

Fibre Processing

In general, Natural fibres if required in aligned manner cannot be used in the raw form for composite fabrication. They must be converted into yarn by spinning and later woven into mats.

In hand spinning the fibres were rolled into short length of 6 to 9 inches, giving a clock-wise twist by hands. When a sufficient quantity has been made, two of these

short lengths are taken in hand together and made into yarns of two plies by giving a counter twist, using both palms. Then when the counter twist reaches near the end of the striking, further pieces of short lengths kept ready are added one after other, while the counter twist by hand is continued till the required length of yarn for a knot is reached. This is reeled in the form of a hank and a knot is made at the end.

The spun yarn was then woven into mats of size 1000 mm x 200 mm x 3 mm. Three different types of mats were woven, viz. Coir–Coir (Bi–directional), Coir–Aloe (Bi–directional), Aloe–Aloe (Bi–Directional) as shown in the Figures 1, 2 and 3 respectively. The entire process was done manually using handlooms. The woven mats were then cut to the required dimensions during composite fabrication.

The random fibres were fabricated manually by hand-rolling which is shown in Figure 4. Care was taken to ensure uniformity of the random mats and avoid lumping of fibres. The fibres were then treated with 10% NaOH, in order to ensure better fibre-matrix interaction and thus reduce moisture absorption. The fibres were soaked in 10% NaOH for 12 hours, then rinsed in distilled water to remove traces of the chemical and then sun-dried.

Composite Fabrication

The composite composes of two matrices; polypropylene and polyester. With respect to being used in the bumper, the following properties of PP are attractive viz., high fracture toughness, ability to be coloured, dirt and dust resistant, corrosion resistant, resistant to temperature fluctuations, resistance to fatigue. And, Polyester was chosen because it can be derived from natural sources such as cuticle of plants and hence are bio – degradable. They have excellent durability and low water absorption. The schematic representation of composite lamination is shown in Figure 5.

The composite was fabricated using hand lay – up method. Such a combination of matrices was chosen instead of a single monolithic polymer because of certain advantages, PP is used in the form of sheets having a higher molecular weight and thus a lower MFI, and consequently it would be difficult to wet the fibres completely. But a polymer with higher MFI has better impact properties. Polyester which is used in the form of a resin, which has a low molecular weight and hence a higher MFI and results in better wetting of fibres. The wetting of fibres is very essential for proper load transfer between the matrix and fibre and also to decrease the adverse effect of environment on the fibres.

Testing

The performance of the composite plate fabricated was evaluated by subjecting it to Charpy Impact test. The standard adopted was ASTM D 256-78 method B. 4 specimens for each sample were tested and the impact energy absorbed was noted.

Water Absorption test

To measure the water absorption by the composite, the samples were taken in the form of bars of 70 mm x 10 mm x 10 mm. They were sun-dried for 24 hours to eliminate any moisture present and weighed. The weight in dry condition before soaking in water was noted as w_1 g. After weighing, the samples were soaked in

distilled water at room temperature (about 30 °C) for 48 hours. The samples were then taken and cleaned using a dry piece of cloth and weighed. The weight in after soaking is taken as w_2 g. The percentage of water absorption is obtained by using Equation 1 and is listed in Table 1.

$$\% \text{ Water absorption} = (W_2 - W_1) \times 100 / W_1 \quad \dots\dots\dots (1)$$

Results and Discussion

SEM Analysis

Effect of Chemical Treatment

The natural fibres are chemically treated to improve their bonding with the matrix. The chemical treatment provided results in a rougher surface on the fibre due to removal of the smooth wax layer which is generally present at the fibre surface. As can be seen from the above micrographs, the surface of the Coir fibres has lesser undulations on the fibre surface while the Aloe vera fibre looks very rough. This helps the Aloe vera fibre to have a better mechanical interlocking with the matrix.

The increased mechanical interlocking also decrease micro-voids at interface region and help minimize water absorption. J. Rout et al (2001) have also shown that the amount of water absorption is greater in the case of un-treated samples when compared to alkali treated samples due to poor wettability and hydrophilic characteristics of the un-treated fibre [5]. M.N. Islam et al (2010) attributed the increase in water absorption in un-treated fibres due to the presence of micro-voids between the fibre and the matrix and the interface which result in large amount of water in-take [6].

Fractography

Fractography studies conducted on the surface of the samples which failed during Charpy testing revealed that the nature of fibre – matrix interaction is very crucial in determining the mechanism of failure which is directly related to the energy absorbed during the process.

The graphical representations of impact strength and specific impact strength for various composites are shown in figures 6 and 7. Similarly the impact strength and specific impact strength values for various composites are listed in Table 2 and Table 3. Coir has poor bonding with the matrix and hence it has some micro-voids at the interface. When subject to impact loading, the impact energy is dissipated along the fibre – matrix interface leading to fibre–pull out or fibre debonding. During this process, a significantly larger amount of energy is up for creating a new surface at the fibre – matrix interface.

On contrast, Aloe vera which has a lot of ridges and cavities on its surface, has a very high bonding with the matrix and hence it exhibits a different mechanism. Due to the high bonding, the weakest part of the composite lies in either the matrix or fibre,

and on impact the weakest link fails first. This process results in significantly lesser amount of absorption of the impact energy.

The SEM images of the fractured surface of various composites are shown in Figure 8 to Figure 13. The fractured surface of the individual fibres is different. In Coir, it shows a serrated edge at the fibre tip, inclined to the fibre axis, whereas, the Aloe vera has a fracture surface which is almost perpendicular to the fibre axis. P. Wambua et al (2003) have stated that the serrated edge absorbs more energy during failure due to the propagation of the crack through a larger cross section area than if it failed normal to the fibre axis [11].

Conclusion

The Charpy impact testing shows that the Coir composite consisting the bi-directional mat with un-treated fibre has the maximum performance, the specific impact strength was comparable to that of GFRPs, but the impact value of the Aloe vera fibre was comparatively lesser due to the fact that it has higher bond strength at the interface between the fibre and the matrix.

Other inferences drawn are that the impact strength of an untreated sample is greater than that of a chemically treated sample due to the formation of high strength interfacial bond in the latter. Due to the same reason, the mechanisms exhibited by the two samples are different from each other. The low interfacial strength composite exhibits fibre pull – out while the higher interfacial strength composite shows matrix / fibre failure. Also the strength of a woven mat is higher than the random fibre.

The moisture absorption test shows that the coir samples absorb more moisture than Aloe vera due to the presence of micro-voids and that the un-treated sample has greater absorption than the treated one.

The other characteristics of the composite that make it competent to be made into a product include the ability of the matrix (PP + Polyester) to be coloured, dust and dirt resistant outer PP layer which is resistant to fatigue (vibrations due to engine) and also temperature fluctuations, the composite is capable of being recycled / bio – degraded. The coir composite also has better processability than the GFRP.

Thus Coir composite is capable of replacing GFRPs if we are satisfied having a thicker bumper than convention which would available at a fraction of cost than original, with the same performance characteristics and which is bio-degradable.



Figure 1: Woven mat – Coir (Bi-directional)

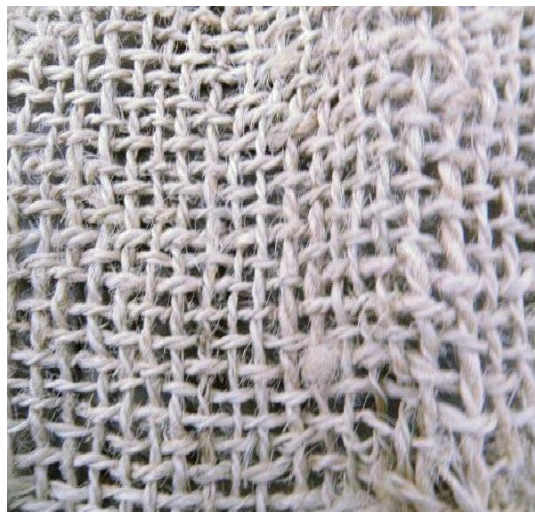


Figure 2: Woven mat – Aloe Vera (Bi-directional)



Figure 3: Woven mat – Coir / Aloe Vera (Bi-directional)



Figure 4: Random mat – Coir

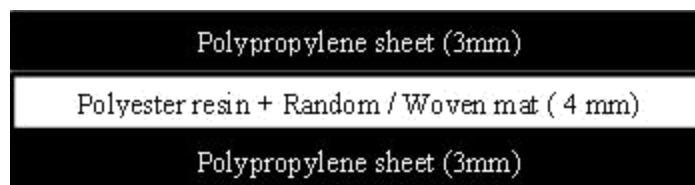


Figure 5: Cross-section view of composite plate

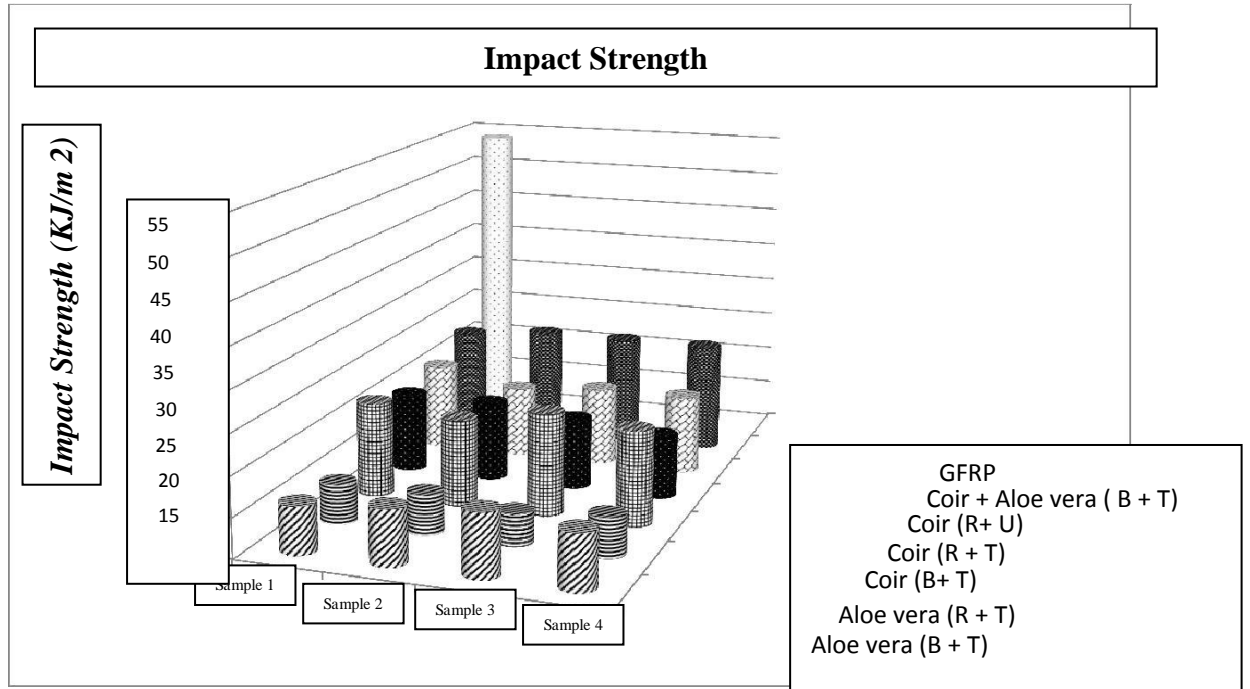


Figure 6: Impact Strength

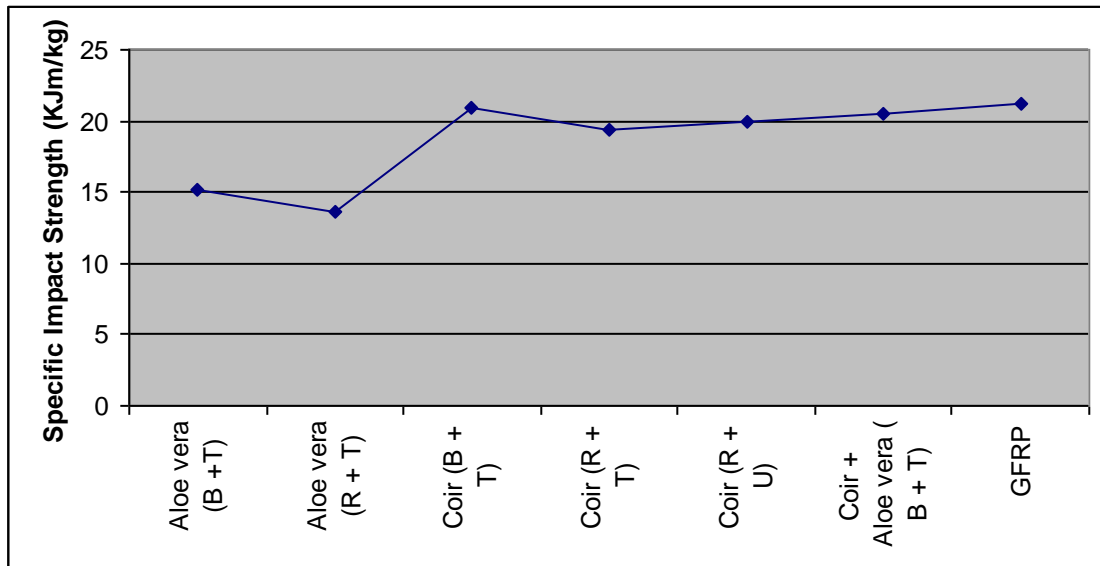


Figure 7: Specific Impact Strength

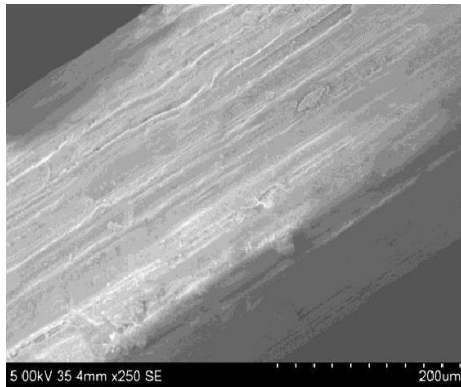


Figure 8: SEM micrograph of treated Coir fibre

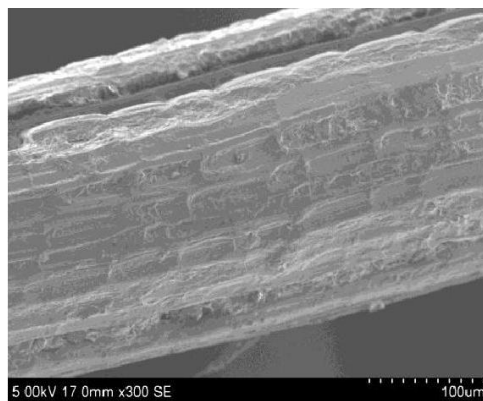


Figure 9: SEM micrograph of treated Aloe vera fibre



Figure 10: SEM micrograph illustrating vera fibre pull-out in Coir / Coir (Bi-directional) Composite



Figure 11: SEM micrograph of Aloe (random) composite showing interface debonding



Figure 12: SEM micrograph of Coir fiber fracture surface

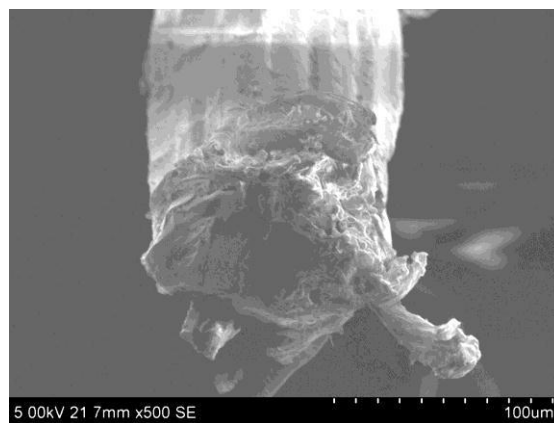


Figure 13: SEM micrograph of Aloe vera fibre fracture surface

Table 1: Water Absorption test

Composites	Weight before soaking (W1 g)	Weight after soaking (W2 g)	Percentage Water absorption (%)
Aloe vera (B + T)	10.517	10.847	5.75%
Aloe vera (R + T)	10.503	10.887	5.69%
Coir (B+ T)	9.455	10.066	7.88%
Coir (R + T)	9.452	10.145	7.92%
Coir (R+ U)	9.454	10.38	9.50%
Coir + Aloe vera (B+T)	9.811	10.5893	7.24%

Table 2: Impact Strength

Composites	Impact Strength (KJ / m ²)			
	Sample 1	Sample 2	Sample 3	Sample 4
Aloe Vera (B + T)	21	22	23	22
Aloe Vera (R + T)	20	20	19	20
Coir (B+ T)	27	26	28	27
Coir (R + T)	25	25	24	23
Coir (R+ U)	26	24	25	25
Coir + Aloe vera (B + T)	28	29	29	29
GFRP	54			

Table 3: Specific Impact Strength

Composites	Specific Impact strength (KJm / kg)
Aloe Vera (B + T)	15.17
Aloe Vera (R + T)	13.62
Coir (B+ T)	20.89
Coir (R + T)	19.40
Coir (R+ U)	20.00
Coir + Aloe vera (B + T)	20.54
GFRP	21.18

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