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Assesing the mechanical behaviour of blended polypropylene-sisal based FRP composite

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ABSTRACT

Recently, massive interest was paid to new technologies dealing with environmental aspect. Perpetuation of natural resources such as natural fibre reinforced polymeric composite leads the upcoming manufacturing industry to search and scrutinize eco-friendly materials. The use of composites in manufacturing equipment and products is taking a very important space in the industry in general. Moreover these materials have unique characteristics when analyzed separately from constituents who are part of them. However, it is known that care must be taken in their manufacture, as the use of appropriate process and the composition of each element, in addition to adherence of fibre, which is a major factor in obtaining the final mechanical strength of the product. One should also take into account whether the composites are environmentally friendly. For this reason, in this work, a composite partially ecological was made, using sisal as reinforcement, which is a natural fibre with renowned mechanical properties as dispersed phase of the composite in the polypropylene resin, in quest of improving the mechanical behaviour of NFRP composite.

1. Introduction

According to Gay (1991), a composite is formed by different materials with distinct characteristics blended together to give tremendous increase in mechanical characteristics when compared with the initial properties of those ingredients, is homogeneous when examined macroscopically and, moreover, may have long or short fibres, which are used in a phase of the material that is called reinforcement. Another phase of the composite is the matrix, which has an agglutinant function and causes the reinforcement to work in an integrated manner, supporting the mechanical stress (Pardini et al., 2006).Several recent technological achievements, particularly those related to relevant applications in areas such as aeronautics, aerospace, petrochemical, shipbuilding, bioengineering, automotive, construction, and sporting goods, among others, became possible only after the advent of structural composites (Levy, 2006).In the quest for sustainability, several researches and works in composites area have been made to ensure environmental preservation and provide a better standard of living to the society. Among the researches in this area, those that seeking the application of natural resources in the preparation of materials are growing, and we could highlight the use of natural fibres of vegetable origin, due to the enormous variety of possible species to be surveyed. Several vegetable fibres are produced in virtually every country and they are usually identified as lignocellulosic materials. Some fibres occur spontaneously in nature, others are grown as agricultural activity and still others are wastes generated mainly by agro industry (Silva et al., 2009). However, according to Sydenstricker et al. (2003), many factors such as weather, age, soil type, extraction method, etc., can seriously affect the structure of plant fibres, their chemical composition and physical properties. As states, natural fibres (lingo-cellulosic) are lightweight and nontoxic, may have high elastic modulus and specific strength, cost about ten times less than the glass fibre and unlike this inorganic fibre, cause less damage by abrasion to equipment and molds (Angrizani, 2006). Among the various natural fibres, one make salient, in the manufacture of composite materials. The use of sisal, jute, hemp, ramie, palm, pineapple, sugarcane bagasse, wood fibres, coconut fibres, etc., which exhibit good mechanical properties as tensile, impact and others in various polymer matrices (Mochnacz et al., 2002).

The versatility of sisal fibres, which adapt to different forming processes of composites such as filament winding, lamination, resin transfer molding, extrusion, injection molding etc., gives to these fibres strategical importance in the development of new composites. Among other advantages of sisal, one can mention the facility of characteristic surface modification of vegetable fibres, their abundance and easiness of cultivation [1]. The hollow helical microstructure of the sisal is responsible for a failure mechanism distinct from other vegetable fibres, and the sisal reinforced composites show a work of fracture similar to the composites of ultra high molecular weight polyethylene (UHMWPE) reinforced by fibre glass (Amico, 2004).The utilization of natural fibre has gained attentions due to the reduction of waste disposal problems especially in agricultural fields, environmental pollution and hence can find various applications in engineering, electronic and automotive fields (Goda et al., 2006). Green composites are environmentally friendly, sustainable, renewable, and biodegradable. Most cellulosic fibres are harvested yearly and the supply should be inexhaustible compared to the limited supply of other synthetic fibres. Natural fibre reinforced polymers also have exhibited numerous advantages such as high mechanical properties, low weight, low cost, low density, high specific properties (Manfredi et al., 2006), posses better

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electrical resistance, good thermal and acoustic insulating properties and higher resistance to fracture. Additionally, the natural fibres reinforced composites can decrease wearing of machines due to its low abrasiveness and absence of health hazardness during processing, application and upon disposal.

2. Fibres and its types

Fibres are hair-like materials that are in discrete elongated pieces, similar to pieces of thread. They can be spun into thread. They can be used as an important component of composite materials. Fibre can be classified into two main groups; they are man-made fibre and natural fibre. In general, natural fibres can be subdivided as to their origin such as plants, animals, or minerals; while man-made fibres can be subdivided to synthetic and natural polymers. The first fibres used by man were natural fibres such as cotton, wool, silk, flax, hemp and sisal. The first man-made fibre was probably glass (Cooke, 1989) [2]. Both natural and synthetic fibres are now available and always being used as fillers in making a good properties of composites. In the last decade, there is a growing interest in Natural fibre reinforced composites because of their high performance in terms of mechanical properties, significant processing advantages, chemical resistance, and low cost/low density ratio [9]. Natural fibre represents environmentally friendly alternatives to conventional reinforcing fibres. The main reward of Natural fibre over traditional ones are low cost, high toughness, low density, good specific strength properties, reduced tool wear, enhanced energy recovery, CO_2 neutral when burned, biodegradability. Because of their hollow and cellular nature, Natural fibre performs as acoustic and thermal insulators, and exhibit reduced bulk density. Lingo cellulosic fibres can be classified in three categories: (1) wood flour particulate, which increases the tensile and flexural modulus of the composites, (2) fibres of higher aspect ratio that contribute to improve the composites modulus and strength when suitable additives are used to regulate the stress transfer between the matrix and the fibres, (3) long Natural fibres with highest efficiency among the lignocellulosic reinforcements [7]. The most efficient Natural fibres have been considered those that have high cellulose content coupled with a low micro fibril angle, resulting in high filament mechanical properties [8]. Depending on their origin, the major classifications of fibres used nowadays are given in Fig 1.

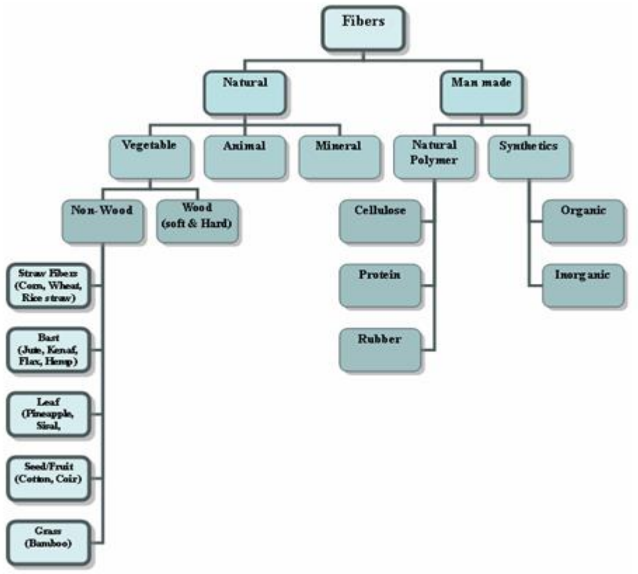


Fig.1 Fibre Classification

Though even glass fibres have considerable advantages, the property of biodegradation in Natural fibres uplifts the usage of Natural Fibre Reinforced Polymeric (NFRP) materials in our daily life. Also, this fibre which doesn't possess any abrasion or emission of toxic gases and the recyclability proves why modern industries and researchers focused their attention in to NFRP composites.

Sisal

Sisal is valued for cordage use because of its strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater. Sisal is used by industry in three grades. The lower grade fibre is processed by the paper industry because of its high content of cellulose and hemicelluloses [3]. The medium grade fibre is used in the cordage industry for making ropes, baler and binders twine. Ropes and twines are widely employed for marine, agricultural, and general industrial use. The higher-grade fibre after treatment is converted into yarns and used by the carpet industry. Fig (2 & 3) shows the extracted sisal fibre processed through manual retting process and the plant through which the leaves were obtained.

Uses of Sisal: products made from sisal are being developed rapidly, such as furniture and wall tiles made of resonated sisal. A recent development expanded the range even to car parts for cabin interiors.

Fig. 2 Sisal fibre

Fig.3 Sisal plant

3. Comparison between Natural and Synthetic Glass fibres

Table.1 shows the various parameters that have to be monitored in natural and synthetic fibres, with considerable advantages while considering natural fibres.

4. Composite and its classification

The term composite can be defined as a material composed of two or more different materials, with the properties of the resultant material being superior to the properties of the individual material that make up the composite. There are two major classifications of composites; they are (1).Natural composites and (2).Artificial or synthetic composites [9]. Fig.4 and Fig.5 shows an example of natural composite and synthetic composite materials. In natural composite material the cellulose which is the reinforcing element which is supported by the matrix lignin in wooden structure. But, in case of synthetic composite the matrix can be of any synthetic material like concrete and the reinforcement nothing but the steel rods blended together to form composite material.

Parameter	Natural fibre	Synthetic Glass fibre
Density	Low	High
Cost	Low	High
Renewability	Yes	No
Recyclability	Yes	No
Energy consumption	Low	High
Distribution	Wide	Wide
CO_2 Neutral	Yes	No
Abrasion to machines	No	Yes
Health risk	No	Yes
Disposal	Biodegradable	Not Biodegradable

Table.1 Fibre parameter

Fig.4 Wood

Fig.5 Concrete

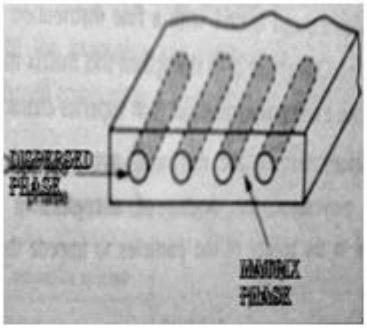


Fig.6 constituents of composites

The two major constituents of composites are

- Matrix phase which is the major constituent of the composite
- Dispersed phase in which the fibres play the major role is clearly indicated in Fig.6

5. Polymers

The term polymer is derived from two Greek words "poly" means many and the term "mer" means parts or units. Thus polymers are composed of a large number of repeating units of small molecule called monomers [4]. The various elements of polymers are plastics, adhesives, coatings, fibres, Biosystems etc. The major classification of plastics is listed in the flow diagram Fig. 7

Polymers may be classified as follows, according to the mechanical response at elevated temperatures as Thermoplastics and Thermosets [6].

Thermoplastics:

Thermoplastic polymers soften when heated and harden when cooled. Simultaneous application of heat and pressure is required to fabricate these materials.

- On the molecular level, when the temperature is raised, secondary bonding forces are diminished so that the relative movement of adjacent chains is facilitated when a stress is applied.
- Most Linear polymers and those having branched structures with flexible chains are thermoplastics.
- Thermoplastics are very soft and ductile.

The commercial available thermoplasts are Polyvinyl Chloride (PVC), Polystyrene, Polymethyl methacrylate etc.

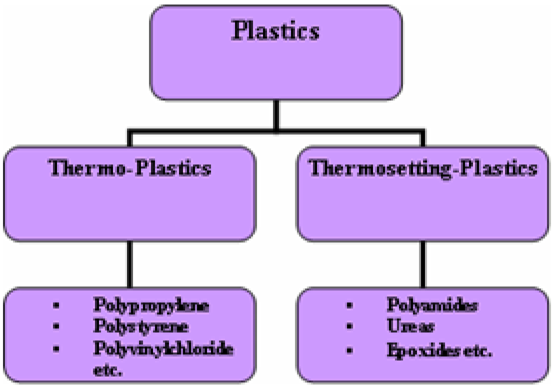


Fig. 7 plastic classification

Thermosets:

In Thermosets, during the initial heating, covalent cross-links are formed between adjacent molecular chains. These bonds anchor the chains together to resist the vibration and rotational chain motions at high temperatures. Cross linking is usually extensive in that 10 to 15% of the chain mer units are cross linked. Only heating to excessive temperatures will cause severance of these cross link bonds and polymer degradation. Thermoset polymers are harder, stronger, and more brittle than thermoplastics and have better dimensional stability[5]. They are more usable in processes requiring high temperatures. Most of the cross linked and network polymers which include Vulcanized rubbers, Epoxies, Phenolic, Polyester resins etc.

6. Fabrication of sisal fibre Polypropylene Composite

Natural sisal fibre reinforced polymeric composite is fabricated by closed-mold system as shown in Fig. 8. The individual view of male and female mold which is mainly used for composite fabrication to make sisal fibre composite is given in Fig.9; the fibres are weighed according to the fibre volume ratio. To maintain homogeneity, the fibres are arranged systematically according to the weight. Firstly, the weighed fibres are divided into two groups and they are knitted together as like a fabric mesh which represents a layer. The procedures are repeated for the second layers. Both layers are separated by polymeric resin placed inside the mold die along with the additives before fabrication as explained below.

Initially the resin is measured according to the desired volume and the catalyst is measured for 0.9% by volume of the resin. The resin is mixed with catalyst and the mixture is stirred. A quarter of mixture is poured to the mold to ensure the mold surface is wetted. Then, the first layer of the fibres is laid gently without disturbing the fibre orientation. Then another quarter of mixture is poured to wet the fibres. Trowel is used to remove the air. Another quarter of mixture is poured before laying the second layer of the fibres. The last quarter of mixture is poured before the mold is closed and screwed by means of hydraulic press. The composite plate is removed from the mold after 24 hours. The procedures are repeated for all specimens. The specimen is ready for testing after 3 days of composite fabrication to ensure the resin is fully cured and hardened. The renewability of natural fibre provides an attractive eco-friendly quality to the resulting composites. We studied the use of fibre gives higher tensile module (*E*) and applicable for using the composite material in the above mentioned application (Table. 2), more effectively than the old one. Below figures shows the compression molding setup used to fabricate the sisal reinforced polymeric composite.

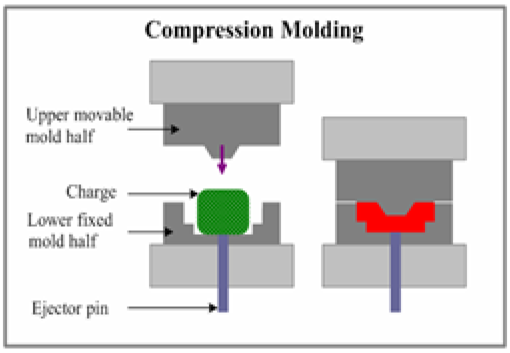


Fig.8 Compression molding principle

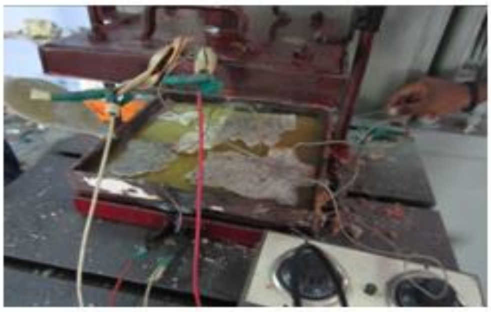


Fig.9 Compression molding Setup

7. Tensile testing

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to uniaxial tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Universal Testing Machine in which various tensile and compression tests can be performed to find the mechanical properties of materials can be identified. In which the different samples based on standards is clamped between the two jaws of the machine and the loads are given to the specimen through the fluid power system with a feed rate of 1mm/min.then calculations are made to identify the required mechanical properties based on the values obtained during the deformation process which is assisted by a computer which is connected to the machine shown in Fig.10.

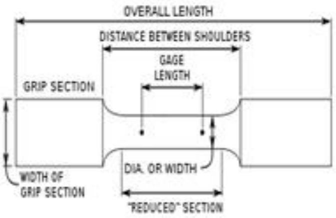


Fig.10 Tensile testing Machine Fig.11 specimen specification Fig.10 Tensile specimen

A tensile specimen is a standardized sample cross-section. It has two shoulders and a gauge section in between. The shoulders are large so they can be readily gripped as shown in Fig.11, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area.Tensile specimens made from NFRP composites is shown in Fig.12. The following Table 2 give examples of test specimen dimensions and tolerances per standard ASTM D3039.

Flat test specimen	
ASTM D 3039:	**All values are in mm**
Gauge length	50.8 ± 0.127
Width	12.7 ± 0.254
Thickness	0.127 ? T? 6.25
Overall length (min)	203.2
Length of reduced section (min)	69.84
Length of grip section (min)	56.5
Width of grip section (Approx)	22.86

Table.2 Flat specimen dimension

Figure 13(a) and (b) shows the composites Young's modulus and ultimate tensile strength as a function of fibre volume fraction, respectively for both L and T tensile samples. The results for randomly oriented composites, reported in a previous work, are also included in this figure for comparison. Irrespective of sample orientation, an increasing trend of Young's modulus and tensile strength with fibre content was found. The observed improvement of the ultimate properties suggests that some kind of interaction between the reinforcement and the polymer matrix exists.

Tensile stress

$$\sigma_t = \frac{F_{max}}{A}$$

Where, A- cross sectional area in mm^2 and F_{max}- maximum load in N

Young's modulus

$$E = \frac{\Delta\sigma}{\Delta\varepsilon}$$

Where, $\Delta\sigma$ = the change in the tensile stress

$\Delta\epsilon$=the change in the tensile strain

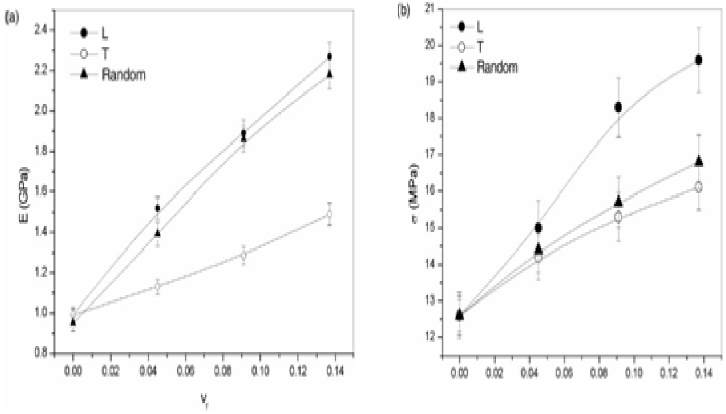
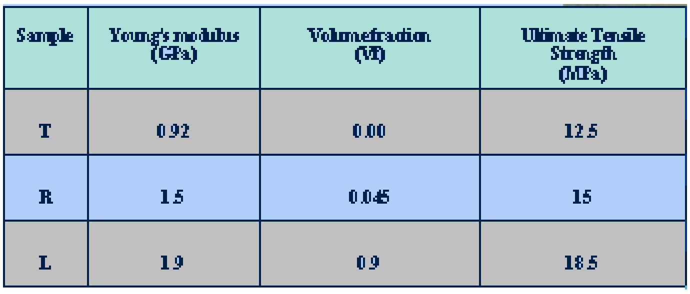


Fig. 13(a) and (b) Young's modulus and UTS as a function of V_f

L sample gives effective young's modulus and ultimate tensile strength which is shown in the Table 3 also Figure 14, shows the material which is fabricated for the testing in which markings were made as per standards and cut in to specimens.



Sample	Young's modulus (GPa)	Volumefraction (Vf)	Ultimate Tensile Strength (MPa)
T	0.92	0.00	12.5
R	1.5	0.045	15
L	1.9	0.9	18.5

Table.3 Values of young's modulus and UTS

Fig.14 Fabricated composite

8. Applications

Typical applications of thermoplastic (PP) sisal fibre blended composite can be used in various sectors where cost effective, Eco friendly material without any compromise in mechanical property required fields like automotive industries and Aerospace industries.

9. Conclusion

Natural fibres show signs of better advantages over the man-made fibres especially in cost, environmental aspects and high specific modulus when compared to synthetic fibres. The drawbacks can be somewhat overcome by introducing chemical or physical treatments to the natural fibres. A lot of trials and testing have been reported in the past few decades, the advancements in materials technology leads the successful usage of treated fibres in majority of the composites. This gives a positive approach to conduct further studies in the characterization of this composite.

10. Scope for Future Work

This study leaves wide scope for future investigations. It can be extended to newer composites using other reinforcing phases and the resulting experimental findings can be analyzed.

Tribological evaluation of coconut fibre reinforced epoxy resin composite has been a much less studied area. There is a very wide scope for future scholars to explore this area of research. Many other aspects of this problem like effect of fibre orientation, loading pattern, weight fraction of ceramic fillers on wear response of such composites require further investigation.

References

[1]. N.Abilash et.al, Evolution of Experimental study on Bamboo based FRP composites. International journal of advances in science and technology, vol. (3) (2011) 47-65.

[2]. A.Grozdanov et.al, Rice straw as an alternative reinforcement in polypropylene composites, Australian journal of crop science 2007.

[3]. K. Murali Mohan Rao et.al, Extraction and tensile properties of natural fibers Vakka, date and bamboo. Materials and design 31 (2010) 508-513.

[4]. P.J.Herrera-Franco et.al, A study of mechanical properties of Short natural fiber reinforced composites. Composites: Part: B 36(2005) 597-608.

[5]. Khosrow Ghavami, Bamboo as reinforcement in structural concrete elements. Concrete composites 27 (2005) 637-649.

[6]. Anil N. Netravali et.al, Composites get greener. Elsevier science 2003.

[7]. Valadez-Gonzalez et.al, Effect of fiber surface treatment on the fiber matrix bond strength of natural fiber reinforced composites. Composites Part: B 30(1999)309-320.

[8]. Navin Chand et.al, High stress abrasive wear study on bamboo. Wear 262 (2007) 1031-1037.

[9]. Paul Wambua et.al, Natural fibres: can they replace glass in fibre reinforced plastics. Composites science and technology 63 (2003) 1259-1264.

[10]. Ian.R.Hardin et.al, an assessment of validity of claims for bamboo fibers. AATCC international conference 2009.

[11]. R.S.P. Coutts, Autoclaved bamboo pulp fiber reinforced composites. Concrete composites 17 (1995) 99-106.

[12]. Shigeyasu amada et.al, Fracture properties of bamboo. Composites: Part: B (2001) 451-459

[13]. J.Y.Zhang et.al, Residual properties of reformed bamboo. Composite science and technology 61 (2001) 1041-1048.