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A Comparative Analysis of a Blend of Natural Jute and Glass Fibers with Synthetic Glass FibersComposites as Car Bumper Materials

Olorunnishola, A.A.G. and Adubi, E.G
Department of Mechanical Engineering Tech., Federal Polytechnic, Ado-Ekiti-Nigeria.
Corresponding Author: Olorunnishola

Abstract: *Bumper is one of the main parts which are used as protection for passengers from front and rear collision. The aim of this study was to analyze and study the structure and material employed for car bumper by one of the car manufacturers. In this study, the most important variables like material structures,hardness and impact conditions were studied for analysis of the bumper beam in order to improve the crashworthiness during collision.The composite bumper samples of HYBRID Cs, PNFC, and GF-C were produced and their mechanical properties were investigated andcompared. The HYBRID Cs(combination of jute and glass fibers) was found to exhibit superior hardness and impact property associated to the commercial GF-C material.Hence, it is obvious that the natural jute fiber composites can undeniably replace the commercial GF-C for automotive components.*
Keywords: *Jute fiber, Glass fiber, composite, car bumper, Mechanical properties*

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I. Introduction

Natural fiber thermoplastic components in the automotive industry can afford the advantages of weight, cost reduction and recyclability, compared to conventional materials. Handlings of natural fibers in automotive exterior and interior components are essential to recover eco-efficiency and renewability. Natural fibers have recently become affordable to automotive industry as an alternative reinforcement for glass fiber reinforced thermoplastics (Jeyanthi and Rani, 2012).

The natural fibers have some advantages over traditional reinforcement materials such as synthetic glass fiber in terms of cost, density, renewability, recyclability, abrasiveness and biodegradability. In modern years the overblown prices for plastics can be reduced by adding natural fibers to thermoplastics which provides both cost reduction and weight reduction. To augment the eco-friendly plastics in automotives the usage of the natural fibers were essential to enhance the degradability and recycling (Saravanaand Mohankumar, 2010). The accessibility of the Jute plant source is plenty in Nigerian rural areas; as a result this sustainable source can be consumed to improve the ecological compatibility.The main advantages of using the natural jutebast fibers in thermoplastics along with polypropylene (pp) are high mechanical properties, thermal properties and recyclability(Saravanaand Mohankumar, 2010). Apart from mechanical properties and thermal properties, recyclability of the materials should be considered for developing the natural fiber thermoplastics to save the green environment.

The fuel efficiency and emission gas regulation of passenger cars are two important issues in these days. The best way to increase the fuel efficiency without sacrificing safety is to employ fiber reinforced composite materials in the cars(Prabhakaran*et al*., 2012). Bumper is the one of the parts having more weight (Prabhakaran*et al*., 2012). In this paper the existing steel bumper is replaced with composite bumper.

A bumper is a shield made of steel, aluminum, rubber, or plastic that is mounted on the front and rear of a passenger car. When a low speed collision occurs, the bumper system absorbs the shock to prevent or reduce damage to the car. In existing bumper the weight is more. In the present trends the weight reduction has been the main focus of automobile manufacturers. Less fuel consumption, less weight, effective utilization of natural resources is main focus of automobile manufacturers in the present scenario. The above can be achieved by introducing better design concept, better material and effective manufacturing process (Prabhakaran*et al*., 2012). Steel bumper have many advantages such as good load carrying capacity. In spite of its advantages, it stays back in low strength to weight ratio. It is reported that weight reduction with adequate improvement of mechanical properties has made composites as a viable replacement material for conventional steel (Daniel *et al*., 1997; Kim, 2008).

An automobile's bumper is the front most or rear most part, ostensibly designed to allow the car to sustain an impact without damage to the vehicle safety system (Pradeep, 2013). They are not capable of reducing injury to vehicle occupant in high speed impact, but are increasingly being designed to instigate injury to pedestrians stuck by cars (Marzbanrad and Kiasat, 2009;Terry, 2008).In driving impact accidents, bumpers do exhibit good elastic spring and damping characteristics under high loads, without becoming plastically or permanently deformed (Busch, 2002).

According to Pradeep (2013) the bumper standards require that; the front and rear bumpers on passenger cars should prevent the damage to the car body, bumper should withstand at a speed of 2 mph across the full width and 1 mph on the corners, bumper should also withstand 5 mph crash into a parked vehicle and that the placement of the bumper is 16 to 20 inches above the road surface.

Automobile bumpers are not typically designed to be structural components that would significantly contribute to vehicle crashworthiness or occupant protection during front or rear collisions. It is not a safety feature intended to prevent or mitigate injury severity to occupants in the passenger cars. Bumpers are designed to protect the hood, trunk, grille, fuel, exhaust and cooling system as well as safety related equipment such as parking lights, headlamps and taillights in low speed collisions (Prabhakaran*et al*., 2012).

Though, polypropylene (pp) is sustainable enough to be used as car bumpers. It may be the most cost efficient but when it comes to structure and durability, it doesn't come close to glass fibers. Polyester and glass fiber still are the best application when it comes to manufacturing (Clerke, 1999). For this research three different composites PNFC (40% Jute fiber), HYBRID Cs (30% jute and 10% synthetic glass fibersand GF-C (40% glass fiber) were used to produce samples of bumper pallets. The specimens were molded according to the ASTM standards (Davoodi*et al*., 2010) using hand layup technique.

II. Methodology

2.1 Materials

According to Prabhakaran*et al*. (2012)car bumpers are expected to meet the following requirements:

- It should absorb more energy while on collision.
- It should have good rust resistance.
- It should have high strength.
- Light in weight.
- Easy to manufacture in large quantity.
- Low cost.

In recent days, various materials like composites are experimented in almost all parts of the automobiles and it has also ventured into bumper. Due to reduction in weight, composite materials are preferred over conventional steel bumper. Composite bumper absorbs more collision energy than steel bumper(Saravanaand Mohankumar, 2010). Therefore the composite materials considered in this work are described below;

Glass Fiber-The aim of fiber reinforced plastics is to combine the stiffness and strength of fibrous material. This material has corrosion resistance, low density and mould ability. The mould ability is its major advantage over jute fiber. The majority of reinforced plastics produced today are glass reinforced epoxy or polyester resins, both of which are thermosetting(Malick, 1998). Glass fibers have also been used with phenolics, silicones, polystyrene and polyvinyl chloride. Glass fibers are the obvious choice as reinforcing agents, principally because of the relative ease with which high strengths can be obtained with this fiber of a few microns in diameters. It is possible to produce composites with a range of strength according to glass content and nature of the reinforcement. The epoxy resins have lower shrinkage than the other resins (Malick, 1998).

Jute Fiber-The primary source of the fiber is Corchorusolitorius (Wikepedia, 2015). Jute fiber is a bast fiber, that is a natural fiber with the following features;

i. Jute fiber is 100% bio-degradable and recyclable and thus environmentally friendly.
ii. It is a natural fiber with golden and silky shine and hence called the golden fiber.
iii. It is cheapest vegetable fiber produces from the bast or skin of the plant's stem.
iv. It is the second most important vegetable fiber cotton, interms of usage, global consumption, production and availability.
v. It has high tensile strength, low extensibility and ensures better breathability of fabrics.
vi. It helps to make best quality industrial yarn, fabric, net and sacks. It is one of the most versatile fabrics that have been used in raw material for packaging, textile, construction and agricultural sectors.
vii. It has the ability to be blended with other fibers, both synthetic and natural, and accepts cellulosic dye classes as natural, basic, vat, sulpur reactive and pigment dyes.

2.2 Fabrication of Composite Bumper

Hand layup technique wasadopted in this work based on its simplicity and effectiveness in making polymer-matrix composite (MPCs) materials(Prabhakaran*et al*. (2012). Continuous fibers were laid on the master mould (the bumper), and the resin precursor was sprayed on it. The composite was then cured of cross linked at the appropriate temperature.

After the polymer – matrix composite was completed using the hand layup, the master mould was returned to the dry room where it was allowed to stay for a day (24 hours), after which it was returned to the workshop where the mould was removed from the master mould and the finishing was carried out on it. (i.e. patching of holes and dents caused on the mould during removal and finally, grinding of the mould to provide smooth surface).

The raw materials used in this research were;

Polymer: Commercial grade polypropylene (PP)

Reinforcement: Twisted jute fiber

Compatibillizer: Maleated polypropylene (MAPP)

Formulation of composites used in this research has abbreviations as follows:

1. 40% wt of natural twisted jute fiber + polypropylene + compatibillizer; PNFC
2. 30% wt of twisted jute fiber +10% wt of glass fiber + polypropylene + compatibillizer; HYBRID Cs.
3. 40% long glass fiber filled, (GF-C), which is available commercially;

III. Results And Discussion

3.1 Mechanical properties

Table 1. Material properties of hybrid materials.

Property	**Jute**	**Glass**
Density (g/cm^3)	1.5	2.58
Strength (MPa)	397 -773	1080 - 2000
Modulus (Gpa)	13 -54	70
Elongation at break (%)	1.7	2.5

Source: Biswas *et al*., (2013) and Volf, (1990).

Samplesof PNFC, HYBRID Cs, and GF-C were subjected to Brinell hardness tests and impact tests using computerized Universal testing machine (UTS) made by Testometricco.Ltd. Rochdale, England while the impact energy was determined with Charpy V-notch machine. The results were also presented in Tables2 and 3.

Table 2: Hardness test result

		Average BrinellHardnessScale			**Average HRB**
S/N	SAMPLE	I	II	III	
A	PNFC	62.5	63.0	65.0	63.5
B	GF-C	52.5	51.5	50.0	51.3
C	HYBRID Cs	62.9	63.8	65.03	64.0

Table 3: Impact test results

		Energy absorbed (J)			**Average energy absorbed**	**Type of specimen**
S/N	Sample	I	II	III		
A	PNFC	10.0	9.8	10.2	10.0	On notched
B	GF-C	10.0	9.0	9.8	9.6	On notched
C	HYBRID Cs	12.0	10.8	12.2	11.6	On notched

3.2 Effect of hardness on fiber properties

Nine samples were prepared and subjected to Brinell hardness test; the results are as shown in Table 2. As shown in Table 2 and Figure 1, it was observed that the Hybrid (juteand glass fibers) composite had the highest resistance to penetration of the surface with hardness strength of 65.53HRB, compared to that of PNFC (pure jute fiber) composite 63.5HRB and GF-C (glass fiber) composite 51.3HRB at the same temperature. The results show the possibility of HYBRID Cs (jute and glass fiber composite) replacing GF-C (Synthetic glass fiber composite)

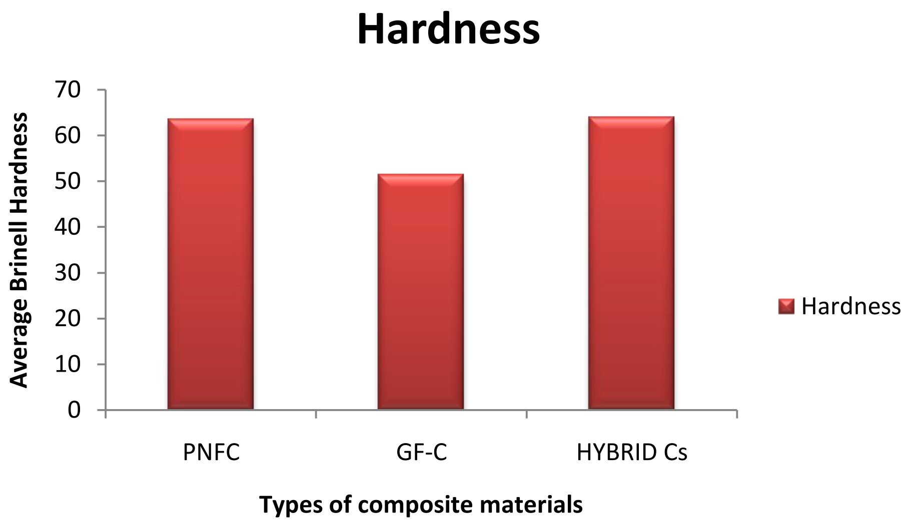

Figure 1: Average Brinellhardness of developed composite bumper material samples

3.3 Effect of Impact Strength on Fiber Properties

Izod impact test methods were conducted according to the ASTM D256-04 standard. Nine samples were prepared and the results were compared with GF-C composites as seen in Figure 2 and Table 3. While comparing the Izod test results, it is proven that the HYBRID Cs has the highest impact strength (11.6 J) while PNFC impact strength (10 J) is slightly higher than that of GF-C(9.6 J).

The bumper materials should have higher impact strength to absorb heavy shock loads during collision. From the results it is clear that the HYBRID Cs can replace the GF-C as a bumper beam.

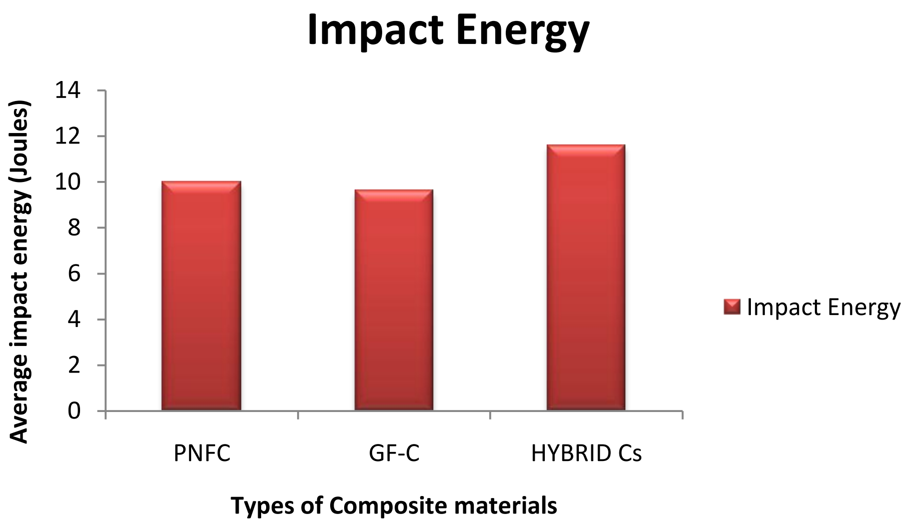

Figure 2: Average impact energy of developed composite bumper material samples

IV. Conclusion

This study concentrates on the mechanical properties of a jute fiber reinforced composites for consumption in automotive components. A twisted jute hybrid material HYBRID Cs, which was fabricated by hand layup method, presents a superior hardness and impact property associated to the commercial GF-C material. This implies that a natural jute long fiber reinforced composites could be utilized in automotive structural components such as bumper beams, front end modules and also in interiors of automobiles. It is clear that the natural jute fiber composites can undeniably replace the commercial GF-C for automotive components.Jute fiber is 100% bio-degradable and recyclable and thus environmentally friendly.

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