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RESEARCH ARTICLE

COMPARATIVE EVALUATION ON MECHANICAL PROPERTIES OF JUTE/BAMBOO-GLASS HYBRID REINFORCED POLYESTER COMPOSITES

Brijesh Gangil and *Sandeep Kumar

Department of Mechanical Engineering, S.O.E.T, H. N. B. Garhwal University, Srinagar 246174, Uttarakhand, India

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ABSTRACT

The man-made fibers (glass, carbon and Kevlar) are widely used as reinforcing material in polymer composites because of high strength to weight ratio and stiffness as compared to conventional materials, i.e. steel, wood and concrete. Beside its primacy to the safety and environmental issues, polymer composites are becoming great contributions to various application areas such as packaging, building construction, automotive parts and electronic industries due to its inherent advantages like flexible, inexpensive and durable. These unfavorable environmental issues of man-made fiber reinforced polymer composites can be minimized by the hybridization techniques. Hybrids can have more than one reinforcing phase and a single resin phase or single reinforcing phase with multiple resin phases or multiple reinforcing and multiple resin phases. The aim of this research is to reduce the weight percent (wt %) of glass fiber and reduced wt % managed by natural fiber (jute, bamboo), so as to minimize the adverse environmental issues. Therefore, the present work is to evaluate the mechanical properties such as tensile strength, flexural strength, impact strength and hardness of mono fiber (glass, jute and bamboo) polyester composites (MFPC). Moreover, the comparison of mechanical properties of MFPC with different combinations of glass/jute; glass/bamboo and jute/bamboo hybrid polyester composites was discussed. The results indicated that incorporation of bamboo fiber with glass fiber reinforced polyester (GFRP) composites exhibited better in tensile strength, impact strength and hardness than the jute fiber reinforced GFRP composites and jute fiber reinforced GFRP composites performed superior in flexural strength.

INTRODUCTION

The polymer composites reinforced with natural fibres are reasonable strong, economical, light in weight, less hazardous and have a potential to be used as structural materials. Bio-fibres like jute, hemp, flax, bamboo and kenaf etc are becoming increasingly important in composite production due to its better strength and stiffness. Despite of the above advantages, they have some limitation also, such as high water uptake capability, and low strength when compared to inorganic fibres such as aramid, glass, carbon. These limitations of natural fibre based composites can be improved by hybridization of such fibre with high strength synthetic fibre which also gives flexibility to the design engineer to tailor the properties of material according to the requirements. Hybrids can have more than one reinforcing phase and a single matrix phase or single reinforcing phase with multiple matrix phases or multiple reinforcing and multiple matrix phases (Thwe, 2003; Fu, 2002 and Kumar, 2013). Many researchers (Kumar Sandeep, 2017; Reis, 2007; Anuar, 2011 and Venkateshwaran, 2012) have reported that the mechanical efficiency of fiber reinforced composite can be improved by combining the man-made fiber with natural fiber in the same matrix. Glass fiber is most commonly used man-made fiber in reinforcing both thermoplastics as well as thermoset polymers. They are low cost, high dimensional stability, tensile strength, chemical resistance and have excellent insulating properties, so various researchers have studied the behavior of combination of different bast /natural fibers with glass fiber in polymer composites. So in order to exploit the advantages of both natural fibre and glass fibre, they are added conjointly to the matrix so that superior, optimal and economical composites can be obtained (John, 2008) Cicala et al. (Cisala, 2009), investigated the properties and performance of hybrid composites with natural fibre/glass fibre for curved pipes. They found out that the tensile and flexural strength of natural fibre laminated based composites were lower as compared to glass fibre laminated polymer composites. For overcoming this problem, they proposed a hybrid composite which showed cost

****Corresponding author: Sandeep Kumar,***
Department of Mechanical Engineering, S.O.E.T, H. N. B. Garhwal University, Srinagar 246174, Uttarakhand, India.

reduction of 20% and weight saving by 23%, when hemp mat was used compared to commercial pipes construction. Zhang et al. (Zhang, 2013), produced flax-glass fibre based hybrid polymer composites. They observed that interlaminar shear strength of the hybrid composites is higher than the glass fibre reinforced polymeric material, and also the tensile failure strain and tensile modulus enhanced with increase the vol % of glass fibre in hybrid composites. Recently such types of combination of fiber (sisal + glass, jute + glass, sisal + jute + glass) were prepared by researchers and observed that the tensile property of (jute + glass) hybrid fiber reinforced composites is much more superior as compared to the others. Flexural property of (sisal + jute + glass) based composite was higher, while the maximum impact strength is of sisal-glass fibre composites was obtained (Ramesha, 2013). Prabhakaran et al. (Durai Prabhakaran, 2014). Performed experimental investigation on flexural potential of hybrid flax/glass epoxy composites. They revealed that flexural modulus of hybrid composites consistently increased when flax fiber layer are replaced by glass fabric from the inner layer to outer layer. The proper arrangements of lamina and glass/flax ratio in composites give enhancement in mechanical properties of hybrid composites (Morye, 2005).

Jute fibre reinforced plastics (JFRP) offer an attractive proposition for cost-effective applications. However, these fibres are identified as producing low strength and modulus composites which can be overcome by effective hybridization with synthetic fibre. The compressive strength of jute-glass hybrid composites in longitudinal direction increases with increase in volume fraction of both jute and glass fibre (Baley, 2002) Research in the progress of bamboo fiber reinforced composites has been rising over the past years, but the mechanical properties of bamboo fibers are not fully exploited in polymer composites. Accordingly, the aim of this work is to analyse the increment or decrement on mechanical properties of jute/bamboo reinforced polyester composites with and without additions of glass fiber. These composite compositions are made up by simple hand lay-up techniques. The properties such as tensile, flexural, hardness and impact are studied and presented in details. The results indicated that the addition of glass in bamboo/jute polyester composite make the composite hybrid and it improve the properties.

Experimental Detail

Materials

In this study bamboo *(Bambusoideae)* and jute (Corchorus capsularis) were supplied by Uttarakhand Bamboo Board (India) in mat form. Unsaturated polyester with a density of 1.12 g/cm^3 was used for the production of all laminates. Glass fiber mat with a density of 2.55 g/cm^3 was purchased from Amtech Pvt. Ltd. India. Jute fiber with following properties is used in this research; Density – (1.3-1.49) g/cm^3, Diameter – (25-230) mm, Tensile strength – (393-773) MPa, Elongation at break load – (1.16-1.5) and Bamboo fiber with properties; Density – (0.6-1.1) g/cm^3, Diameter – (30-260) mm, Tensile strength – (140-230) MPa are used to fabricated fiber reinforced composite material.

Preparation of fiber reinforced composites

Three types of fibers; one is synthetic fiber (glass fiber) and other two natural fibers (jute and bamboo) are used in this study. Initially the natural fibers are dried under sunlight for 3 to 6 hr. The hand lay-up is the simplest technique for fabrication of composite material. The low temperature curing unsaturated polyester resin corresponding hardener ratio is (10:1) and cobalt accelerator is mixed in a suitable ratio. The first layer is fiber laminate, fill the polyester resin over the fiber lamina in case of mono fiber reinforced composites. For the hybrid composites, first layer is glass fiber, fill the polyester matrix over the glass fiber and then fill the natural fiber (jute or bamboo over the resin before the resin gets dried and the succeeding layers are filled. The air bubble are formed during fabrication are gently squeezed out by the roller. Finally these laminated composites are post cured under the 22 kg loads for 24 hr. and the designations of these composites are given in table 1.

Table 1. Compositions and Designation of composites

Compositions (wt %)	Designation
25% Bamboo + 75% Polyester	BNC
25% Jute + 75% Polyester	JNC
25% Glass + 5% Polyester	GFC
12.5% Glass + 12.5% Jute + 75 % Polyester	GJHC
12.5% Glass + 12.5% Bamboo + 75 % Polyester	GBHC
12.5% Bamboo + 12.5% Jute + 75 % Polyester	BJHC

Mechanical Testing

The flat specimens are used for tensile test. A uniaxial load is applied through both ends. The dimension of the sample for the test is 150mm × 10mm and thickness of sample varies with different fiber compositions. The test is performed in the universal testing machine Instron-1195 at cross head speed of 10 mm per minutes and the test is repeated two times for each specimen to obtain mean value of tensile strength. The ASTM standard method for tensile properties of fiber reinforced composite have the designation D3039-76. The ASTM: D790 standard is used for determining flexural strength of different samples and test conducted on UTM. Vickers hardness test was conducted on the specimen using a standard Vicker hardness tester. A load of 30 kN applied on the specimen for 20 second using 2.5 mm hard metal ball indenter and the indentation diameter was measured using a microscope. The hardness was calculated by the mean value of hardness at three different locations in specimen. High strain rates or impact loads may be expected in many engineering applications of composite materials. The suitability of a composite for such applications should therefore be determined not only by usual design parameters, but by its impact or energy absorbing properties.The Charpy impact test was carried out in this study. In Charpy method the sample size is 55mm× 10mm×10mm and v-notch t/3 were taken. The scale of the machine is 1 division = 2 joule.

RESULTS AND DISCUSSION

Tensile Properties

The tensile property of mono natural fiber based polyester composites (MNFC) would be increased by the use of hybridization with synthetic fibers. Yaacob et al. (Malek Yaacob, 2011), have find out the effect of hybridization of glass fiber composites with natural fiber on mechanical properties of composites. The authors revealed that high strength, low ductility, and low toughness were obtained when higher amount of glass fiber incorporated with low wt% of kenaf fiber. Atiqah et al. (Atiqah, 2014), examined the cellulosic kenaf-glass fiber based polyester hybrid composites by sheet molding process and also treated natural fiber with mercerization. The authors observed that tensile and flexural strength of surface modified hybrid composites was slightly better than untreated one. They also revealed that 15/15 wt % kenaf/glass hybrid material shows superior mechanical properties as compared to other combinations of weight percentage. By the help of these researches it is possible to enhancement of tensile properties in case of jute and bamboo fiber polyester composites with the help of glass fiber reinforcement, so as to target new class of composites with minimize utilization of glass fiber. The tensile properties of the composites BNC, JNC, GFC, GJHC, GBHC and BJHC are presented in Fig 2. The tensile strengths of the composites with mono BNC, JNC and GFC are recorded as 46.67 MPa. and 33.89 MPa. and 86.76 respectively. It was noticed that the tensile properties of combination of natural and synthetic fiber polyester composites increases as compared to MNFC. GJHC, GBHC, and BJHC are recorded as 64.08 MPa. , 80.56 MPa. and 60.32 MPa. , these increments may be due to support of glass fiber in MNFC.

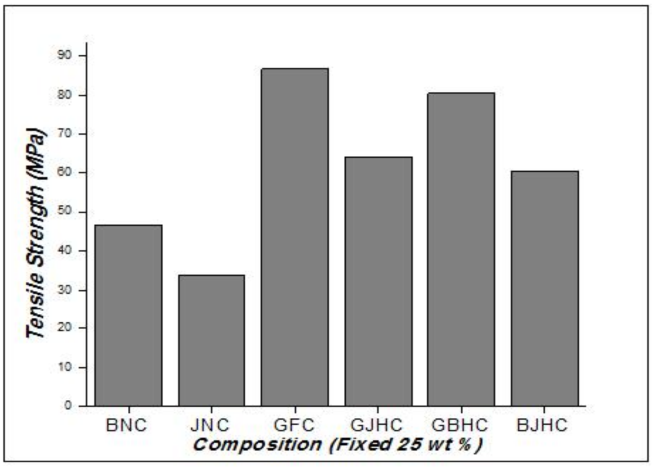

Figure 2. Variation of Tensile Strength with Fabricated Composites and Tensile Test Specimens

Flexural properties

The graph comparing flexural strength Vs compositions of all specimens is shown in fig 3. From the figure it is asserted that the flexural strength of GJHC polymeric material is superior among all hybrid specimens. Even through the natural fiber reduce the environment risk and hybridization of natural fiber with made-made fiber are economically better then single used synthetic fiber reinforcing materials. Hence these work obliging to attain a favorable flexural strength of natural/synthetic fiber hybrid composite material with reduced cost and highly eco-friendly as compared to other synthetic fiber reinforced composites.

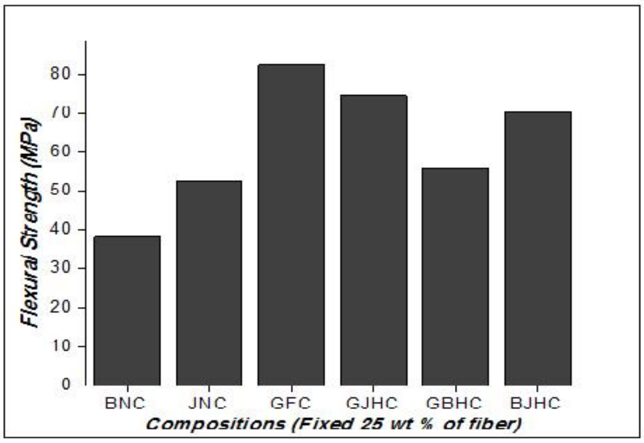

Figure 3. Variation of Flexural Strength with Fabricated Composites and Flexural Test Specimen

Hardness

The graph between hardness and fabricated composites is shown in Figure 4. It has been found that a hardness property of materials increases in case of hybridizations. GFC specimen has better hardness in overall mono fiber reinforcing materials. GBHC gives superior hardness among the specimens MNFC and hybrid composites. The maximum surface hardness value of 34 Hv (Vicker hardness) is obtained from Glass/bamboo fiber hybrid polyester composite. Ramnath et al. (Ramnath, 2014), investigated the mechanical properties of jute-flax based glass fiber reinforced polymer composite (GFRP). The authors has revealed that hardness of jute-flax based GFRP are more comparatively mono jute-glass FRP composites, but mono-jute GFRP excel well under impact loading and ultimate shear strength superior.

Impact Energy

The impact energy of composites depends on the factors like chemical bonding between fibre and matrix and the toughness of fibre reinforcement.

The notched Charpy impact energy for different composites is presented in Fig. 5. *The results indicated that the maximum impact energy is absorbed by GBHC followed by GJHC and BJHC.*

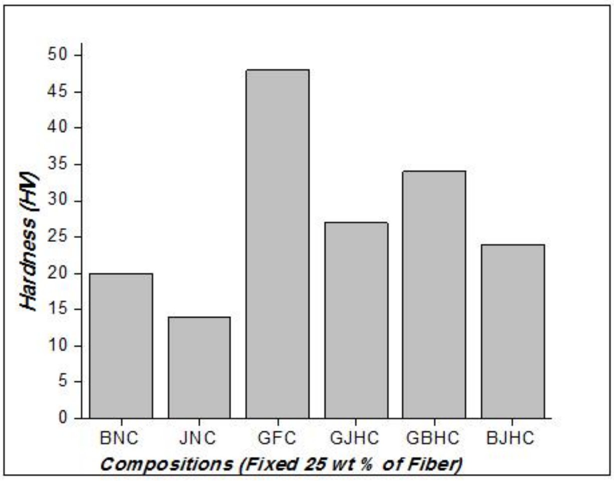

Figure 3. Variation of Hv with Fabricated Composites and Hardness Test Specimen

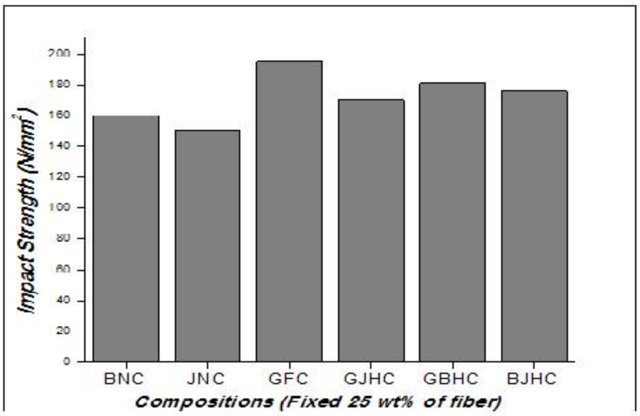

Figure 3. Variation of Impact Strength with Fabricated Composites

Conclusions

Effects of hybridization on tensile, flexural, hardness and impact properties of glass-jute/bamboo unsaturated polyester composites have been experimentally evaluated. From the results of this investigation, the following conclusions are drawn.

- The successful fabrications of a new class of polyester based composites reinforced with bamboo/jute and glass have been done.
- Beside as an interesting alternative for reducing the inconvenience of synthetic fiber utilization, bamboo and jute also give the advantages if we preserving and conserving its.
- Incorporation of glass in natural fiber (jute/bamboo) reinforced composites enhance the properties of resulting hybrid composites.
- It has been observed that the mechanical properties of composites such as tensile strength, flexural strength, hardness and impact strength greatly influenced by the hybridization of MNPC with glass fiber, so as to achieve desirable mechanical properties with minimization the uses of glass fiber.
- GBHC (12.5 wt % bamboo and 12.5 wt% glass) composite exhibited optimum tensile, hardness and impact strength among all hybrid polyester composites. GJHC shows better in flexural strength.
- From this report, it is possible to minimize human hazard and critical environmental issues in the field of polymer composites by the help of natural fibers which are abundantly available in nature.

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