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Research Article

Evaluation of Mechanical Properties of Jute Reinforced Sugarcane Bagasse Composite

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Abstract

Composite is a material composed of two or more distinct phases and has bulk properties which are significantly different from the constituent materials. This composite materials has been made by using sugarcane bagasse as a filler, jute natural fiber as reinforcement material with PVA as matrix. A specimen product of such a composite has developed through layer by layer method at a certain temperature and pressure to suit the processes. The composite was tested for its mechanical properties like tensile, bending and compression strength by using conventional testing machines and the results are recorded and compared with the existing wood chipboard. Recently the interest in composite materials reinforced with natural fibers has considerably increased due to the new environmental legislation as well as consumer pressure that forced manufacturing industries to search substitutes for the conventional materials. The main objective of the study is to evaluate the mechanical properties and characterization of jute reinforced bagasse composite.

Keywords: Jute fiber; Sugarcane Bagasse Composites; Tensile test; Bending test; Compression test.

Introduction

Ceramics and Plastics have been the foremost promising materials in the world market. The volume and numbers of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly [1]. Nowadays, composites have become one of the most important engineering materials in different applications. The demands for composites are steadily increasing as composites are more preferred compared to other materials such as metals and ceramics. The main reason for this is because composites are relatively cheaper and have high availability. With an advantage of that, the properties of composites can be altered according to the desired applications [2]. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to complicated niche applications [1].

However, the trend of the world today leans toward biodegradable or "green" materials which are more environmental friendly. These "green" materials are also sustainable as it comes from renewable resources. Even though composites have many uses in the industry, it is actually a better idea to apply "green" composite or biocomposite [3]. Biocomposites are a type of composite where either one or both of the constituent materials; matrix and reinforcement are of biological origin [4]. As mentioned before, at least one of the constituent materials of the bio-composite must be of biological origin. In this study, bagasse fibers are used as the filler material with jute and PVA wood glue for the biocomposite.

Both matrix and reinforcement are essential to form the desired composite. These two constituent materials; matrix and reinforcement is mixed together in a proportion and shaped to produce the desired composite. This combination of the chemical and mechanical properties of these two groups of constituent materials will produce a composite with different properties than the constituent materials [4]. With these background information, in this research work an attempt has been made to produce a composite materials by using jute as reinforcement, PVA as a matrix and waste sugarcane bagasse as filler. In recent

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years, there has been an increasing trend toward more efficient utilization of residual agro-industrial products such as sugarcane bagasse (generally known as "bagasse") [4,5]. Bagasse is the fibrous residue of sugarcane after crushing and the extraction of sugarcane juice and is one of the largest residual agriculture products in the world [5,6,7]. Sugarcane bagasse wastes are chosen as an ideal raw material in manufacturing new products because of its low fabricating costs and high quality green end material [4,8].

All plant fibers are composed of cellulose while animal fibers consist of proteins (hair, silk and wool) [9]. Among the plant origin fibers jute and sisal are the most widely used because of their availability and strength. Therefore, jute fiber is used in this research work as a reinforcing material. Jute fibre is 100% bio-degradable and recyclable and thus environmentally friendly. Jute is a bast fiber used for sacking, burlap, and twine as a backing material for tufted carpets. It is a long, soft, shiny fiber that can be spun into coarse, strong threads. It is one of the cheapest natural fibers, and is second only to cotton in amount produced and variety of uses [10,11,12].

Polyvinyl acetate is a colorless, nontoxic thermoplastic resin prepared by the polymerization of vinyl acetate. It is one of the most widely used water-dispersed resins. PVAC resins produce clear, hard films that have good weather resistance and withstand water, grease, oil, and petroleum fuels. Additional properties are high initial tack, almost invisible bond line, softening at 30-45, good biodegradation resistance, poor resistance to creep under load, and low cost. Such natural fibers are low-cost fibers with high specific properties, low density, and eco-friendly. It will be an alternative way to develop the biocomposites which can be particularly used for daily needs of common people whether it is house hold furniture, house, fencing, decking, flooring, and light weight car components or sports equipment's [4]. The creation of bio-composite fibre board can also used in wall construction and is potentially to contribute of making cost effective home possible [13].

With these ideas, the scope of this work was to study the use of jute fiber as reinforcement and sugarcane bagasse as filler in low cost resin matrix composites. Their low cost, easy availability and aesthetic designs will be the main driving force to transform the depended present to sustainable future. Significant research is currently underway around the world to address and overcome the obstacles mentioned above. This effort to develop biocomposite materials with improved performance for global applications is an ongoing process.

Materials and methods

Materials

In the present research work, in order to produce jute reinforced bagasse composites the following materials and equipment were used those are jute fiber, waste sugarcane bagasse, PVA glue, mold with presser, timbers, and plastic.

Manufacturing methods of composite

There are numerous methods for fabricating composite components. Some methods have been borrowed (injection molding, for example), but many were developed to meet specific design or manufacturing challenges. Selection of a method for a particular part, therefore, will depend on the materials, the part design and end-use or application [14]. Hand layup is the most basic fabrication method for composites which typically consist of laying dry fabric layers, or "plies," or prepreg plies, by hand onto a tool to form a laminate stack. Resin is applied to the dry plies after layup is complete (e.g., by means of resin infusion). In a variation known as wet layup, each ply is coated with resin and "debulked" or compacted after it is placed.

Design of the jute reinforced bagasse composite

A composite is fabricated combining jute a natural fiber with a polymer resin a matrix through layer by layer method at a suitable temperature for bonding of the materials and curing process to take place. The fabricated specimen composite were tested for its mechanical properties using conventional testing machines and the values recorded. The recorded results are compared with the chip board of wood fiber. The results obtained were analysed and discussed to identify its properties and find suitable applications.

Chipboard was made by bonding together wood particles with an adhesive under heat and pressure to form a rigid board with a relatively smooth surface. In this research work the same process was taken and the filler material (wood particles) replaced by sugarcane bagasse.

Proportion of the reinforcing, matrix and filler materials

After knowing of the sample which achieved the best strength depending on the mixing proportions (Table 1), the entire samples were fabricated as per the optimized conditions and compared with the chipboard of wood fiber.

Table 1. Proportion of the bagasse fiber and PVA wood glue

Sample	Bagasse fiber, g	PVA wood glue, g
1	100	10
2	100	20
3	100	30
4	100	40

Processes to manufacture the composite

Sugarcane bagasse were collected and crashed to small particles that are suitable for the process. This the crashed bagasse chips were glued with resins. Spreading out of the mixture on the plate and placing the reinforcement material on the mixture with different orientation. Covering the edge of the plate and pressing with heated presses (Figure 1). Finally finishing and cutting the produced board as per the requirement and conducting test to characterize the products.

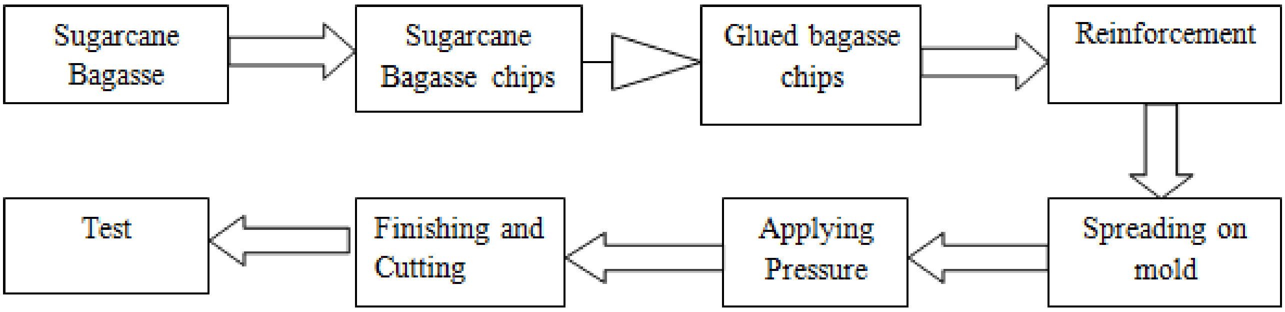

Figure 1. Processes to manufacture the composite

Characterization of the composite

The manufactured composite materials properties were characterized and compared with the wood chipboard. The tensile strength was measured by universal strength tester according to ASTM D3039 standard. Compression test were done by box compression testers according to ASTM E209 standard. Bending strength test was measured by 3 point bending test according to ASTM D790 standard.

Result and discussion

Measurements were made for the determination of tensile, compressive, and bending strength of both the jute reinforced bagasse composite (Table 2) and the existing wood chipboard according to ASTM standard and compared.

Tensile strength analysis

All tensile strength tests was conducted as per ASTM in 100 kN servo electronic universal testing machine. Remarkable differences were observed in the stress-time behavior due to addition of different weight percentage of bagasse and jute fibers. The results of both jute reinforced bagasse composite and existing wood fiber chipboard was presented in the Tables 3.

Table 2. Preparation of the samples for tests

Type of test	Number of samples	Length (mm)	Width (mm)	Thickness (mm)
Tensile Strength	3	400	88	14
Bending strength	3	700	88	14
Compression strength	3	100	88	14

From the Table 3 and Figure 2 test results a remarkable differences were observed in the ultimate tensile strength of both the new jute reinforced bagasse composite material and the existing wood fiber chipboard material. The new jute reinforced bagasse composite material has a mean tensile strength value of 6.91 which is higher than the existing chipboard which has a mean tensile strength value of 5.3. The increase of ultimate strength of the new product is due to using of both bagasse and jute fibers instead of wood chip. However, significant increase in modulus of elasticity is seen due to the presence of bagasse content in the material. Without bagasse fiber the increase in modulus of elasticity is less, but only bagasse fiber improves the modulus elasticity property. The percentage elongation of material also increases with the presence of the fiber.

Bending strength analysis

Bending test is simple and qualitative test that can be used to evaluate ductility and soundness of the material. All bending strength tests was conducted as per ASTM in 100 kN servo electronic universal testing machine. Remarkable differences were observed in the stress-time behavior due to addition of different weight percentage (wt%) of bagasse and jute fibers. The results of both jute reinforced bagasse composite and existing wood chipboard was presented in Table 4.

Table 3. Mean tensile test result of both new and chipboard of wood fiber

Jute reinforced bagasse composite			
Sample	Area (mm^2)	Maximum force (kn)	Tensile strength (Mpa)
1	1232	8.31	6.81
2	1231	8.62	7.02
3	1232	8.39	6.91
Mean	1232	8.44	6.91
Existing wood chipboard			
Sample	Area (mm^2)	Maximum force (kn)	Tensile strength (Mpa)
1	1232	8.1	6.5
2	1231	6.2	5
3	1232	5.4	4.4
Mean	1232	6.55	5.3

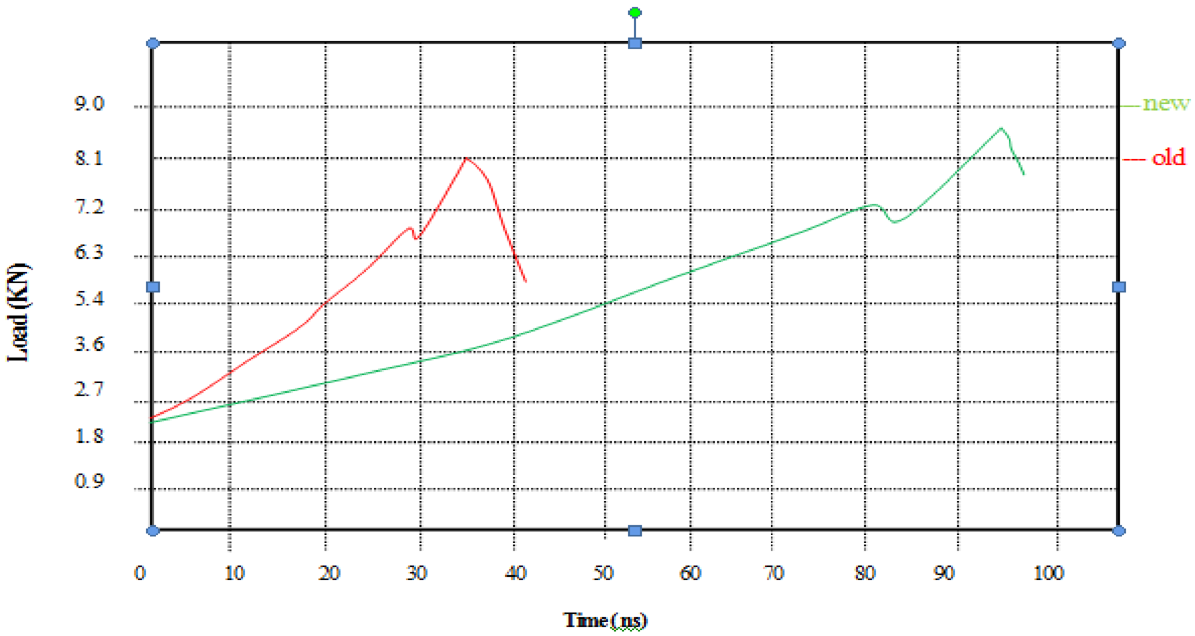

Figure 2. Tensile test result of both new and wood fiber chipboard

From the Table 4 test result it was observed that both samples have different bending strength with the same cross-sectional area. This investigation showed that the mean bending strength value of new jute reinforced – bagasse fiber composite is found to be 14.1 Mpa. These value is higher than and the existing wood fiber chipboard which is 12.6. Hence, it can be concluded that proper combination of the bagasse and jute fiber hybrid composite material may have a varieties of application when weight and strength would be the critical parameter in the design.

Compression strength analysis

The compressive strength of both jute reinforced bagasse fiber hybrid composite materials were determined by 100 kN load using compression testing machine at 1 mm/min cross head speed under displacement control mode. The compression strength test result of the jute reinforced bagasse composite and the existing chipboard was presented in the Table 5.

Table 4. Mean bending strength test result of both new and the wood fiber chipboard

Jute reinforced bagasse composite			
Sample	Area (mm^2)	Maximum force (kn)	Maximum strength (Mpa)
1	33.24	0.51	13.37
2	33.24	0.53	14.56
3	33.24	0.52	14.25
Mean	33.24	0.52	14.1
Existing wood chipboard			
Sample	Area (mm^2)	Maximum force (kn)	Maximum strength (Mpa)
1	33.24	0.4	11.99
2	33.24	0.44	13.29
3	33.24	0.42	12.53
Mean	33.24	0.42	12.6

From Table 5, it was observed that the jute reinforced bagasse composite material has a mean stress value of 0.8265 which is higher than the existing wood chipboard which has a mean tensile strength value of 0.745. This tells as rigidity and compressive strength of the jute reinforced composite are higher compared to that of the existing chipboard. Jute reinforced bagasse composite can resist higher amount of stress than the existing product i.e. the new jute reinforced bagasse product has higher compressive strength value than the existing product. This is because of the presence of jute fiber as reinforcement.

Table 5. Compression test result of both new and chipboard of wood fiber

Jute reinforced bagasse composite		
Sample	Area (mm^2)	Stress (Mpa)
1	1176	0.8372
2	1176	0.8213
3	1176	0.8212
Mean	1176	0.8265
Existing wood chipboard		
Sample	Area (mm^2)	Stress (Mpa)
1	1176	0.7219
2	1176	0.7644
3	1176	0.7487
Mean	1176	0.745

Conclusions

In the present investigation an attempt was made to manufacture a composite material which is made from jute reinforced bagasse composite and compared with the chipboard of wood fiber. From the above discussion it was concluded that the tensile, bending and compression strength of the new manufactured jute reinforced bagasse composite was better than the existing wood chipboard. This result shows that the produced composite materials have the tendency to replace the existing chipboard in the market in various applications. Natural fibers and composites made from natural sources integrate the sustainable, eco-friendly and well-designed industrial products which can replace dominance of synthetic based products in future. Interfacial adhesion between natural fibers and matrix will remain the key issue in terms of overall performance, since it dictates the final properties of the composites. The utilization of bagasse fibers for fabrication of biocomposites by using advance technology transforms future of coming generation. Bagasse fiber is obtained from a source which is known for its renewability in terms of fast growth and better mechanical properties. The well designed and engineered products from the bagasse fibers can help in making new revolution to sustain our natural resources. Thereby, based on this background information the bagasse fibers can be utilized for advance and engineered product development for various applications. It will be an alternative way to develop the such composites which can be particularly used for daily needs of common people whether it is house hold furniture, house, fencing, decking, flooring, and light weight car components or sports equipment's. Their low cost, easy availability and aesthetic designs will be the main driving force to transform the depended present to sustainable future.

Conflicts of interest

The author declares that there is no conflict of interest.

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