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Evaluation of the Effect of Fiber Volume Fraction on the Mechanical Properties of a Polymer Matrix Composite

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Abstract

The possibility of utilization of the fibres made from bagass as reinforcement in polyester matrix composite was evaluated. The various composite formulations were prepared using 0%, 2%, 4%, 6%, 8%, 10%, 15% and 20% bagass fibres as the reinforcement. For tensile strength, samples were prepared according to ASTM D412 and tensile strength of standard and conditioned samples was calculated, using INSTRON 1195 at a fixed crosshead speed of 10mm min^{-1}, for microhardness, the sample was indented using Durometer following ASTM procedure No.D2240 and the reading is noted from the calibrated scale. It was observed that The UTS, Modulus of elasticity and extension to break of the polyester resin matrix composite increase with the amount of bagass fibre up to a certain threshold and then begins to reduce with further increase in the amount of bagass fibre. It was concluded that the bagass fibres are providing a reinforcement effect in polyester matrix composites and the maximum reinforcement is achieved at around 10% by weight of bagass fibre content.

Keyword

Reinforcement; Polyester Matrix; Composite; Bagass Fibre

Introduction

The common practice of considering a natural fiber as an undesirable waste, results in its burning or disposal on landfills. In any case, these practices contribute to pollution problems. Therefore, in order to preserve the environment, it is necessary to find economically feasible solutions to the increasing amount of natural fiber wastes. This can be achieved through the understanding of natural fibers as recyclable materials, which could be used for different applications, ranging from handicrafts to reinforcement elements for composite materials. [1]

Technologically, the most important composites are those in which the dispersed phase is in the form of fiber [2]. The arrangement/orientation of the fibres relative to one another, the fibre concentration and distribution all have significant influence on the strength and other properties of fiber reinforced composites. Some critical fiber length is necessary for effective strengthening and stiffening of the composite material. [3]

Several people have worked in this direction [4-6] that natural fibers from the coconut fruit crust, sugar cane bagass that are nowadays disposed as an unwanted waste, might be seen as a recyclable potential alternative to be used in polymeric matrix composite materials.

The objective of this work is to evaluate the possibility of utilization of the fibers made from bagass as reinforcement in a polymer matrix composite, to investigate the effect of the fiber volume fraction on the mechanical properties of the polymer matrix composite obtained and arrive at an optimum recipe for the production of such materials.

Materials and Method

The materials and equipment used for this project work are: Polyester resin, Methyl Ethyl Ketone Peroxide (catalyst), Cobalt 2% in solution as accelerator, Bagass Fibre, Poly Vinyl Acetone as mould release agent, and Ethanol: This is used to clean off the left over of polyester material from the beaker and other apparatus. Weighing balance: This is used to measure the polyester resin, fibre, accelerator and catalyst.

Quantities of each of the materials (Polyester resin, fibre, catalyst, and accelerator) were weighed to conform to the formulation. The Teflon mould was cleaned and its surface coated with Poly vinyl Acetone to serve as mould release agent. It was left to dry and then the top and bottom parts were joined with bolts and nuts as seen in Plate1.0 (a), (b) and (c) (see the Appendix). This was to ensure the formation of a pure resin on the outer surface of the moulding. The polyester resin was held in a glass beaker. The accelerator was added and the mixture was stirred for 3 minutes. After which the catalyst was added and stirred for additional 2 minutes. The fibre was then added gradually and stirred to allow for proper dispersion of fibre within the gel-like mixture. The prepared formulation of the resin containing curing additives (catalyst and accelerator) and filler was poured to fill the mould. When fully hardened, it was stripped from the mould and trimmed to size using a hand file. Several samples of varying filler content, ranges from 0 - 20% (0%, 2%, 4%, 6%, 8%, 10%, 15%, 20%) were prepared using the above described method.

Mechanical test

Tensile Testing

In the present study, tensile tests were performed on INSTRON 1195 at a fixed crosshead speed of 10mm min^{-1}. Samples were prepared according to ASTM D412 (ASTM D412 1983) and tensile strength of standard and conditioned samples was calculated.

Micro hardness testing

The sample was indented using Durometer following ASTM procedure No.D2240 and the reading is noted from the calibrated scale.

Results and Discussion

The results obtained from the tests are recorded in Tables 1 and 2 in the Appendix.

The variation of the various properties determined with the amount of bagass fibres is depicted in Figures 1, 2, 3, 4 and 5.

The results also show that addition of Bagass fibre causes brittleness and reduction in the ductility of the polyester. Brittle fracture takes place without appreciable deformation, and by rapid crack propagation.

Conclusion

It can be concluded that the UTS, Modulus of elasticity and extension to break of the polyester resin matrix composite increase with the amount of bagass fibre up to a certain threshold and then begins to reduce with further increase in the amount of bagass fibre.

Strain of the polyester resin matrix composite decreases with the amount of bagass fibre.

The hardness of polyester resin matrix composite increases generally with the addition of bagass fibre.

The bagass fibers are providing a reinforcement effect in polyester matrix composites and the maximum reinforcement is achieved at around 10% by weight of bagass fibre content.

It can be observed from Figures 1 and 2 that the ultimate tensile strength and the modulus of elasticity increase respectively with increase in the amount of bagass fibres in the sample. These properties reach maximum value at around 10% bagass content, and then begin to decrease with further increase in the amount of bagass fibres. The same trend is observed in Figure 4 which shows the variation of the extension to break of the sample produced with the amount of bagass fibres content.

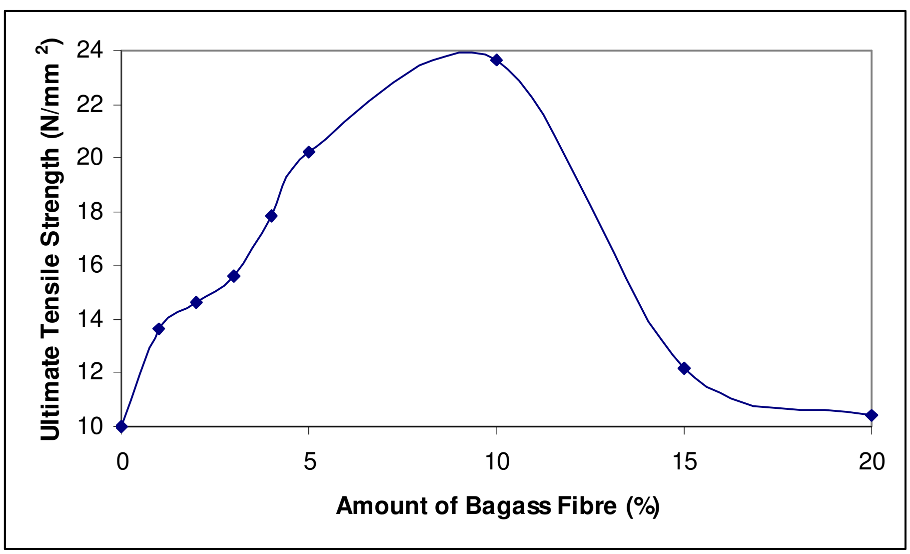

Figure 1. *Variation of the composite ultimate tensile strength with the amount of bagass fibers.*

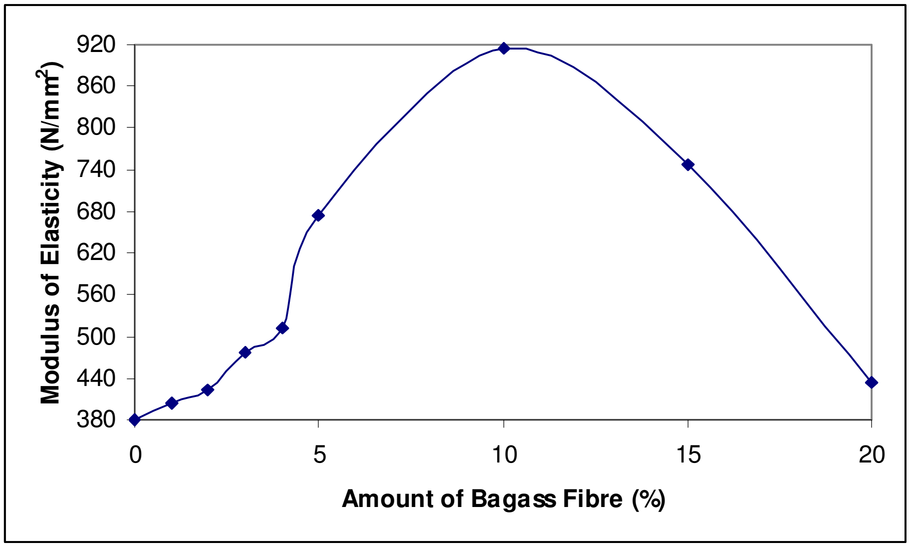

Figure 2. *Variation of the composite modulus of elasticity with the amount of bagass fibers.*

In Figure 3, the strain is observed to be lower even though is stress is high because the molecules are tightly bound to each other. If however the molecules were loosely bonded to each other, a relatively small amount of stress would have caused a large amount of strain. Figure 4 shows that the extension at break increases as the fibre content increases up to 10% after which it decreases as the fibre content increases above 10%.

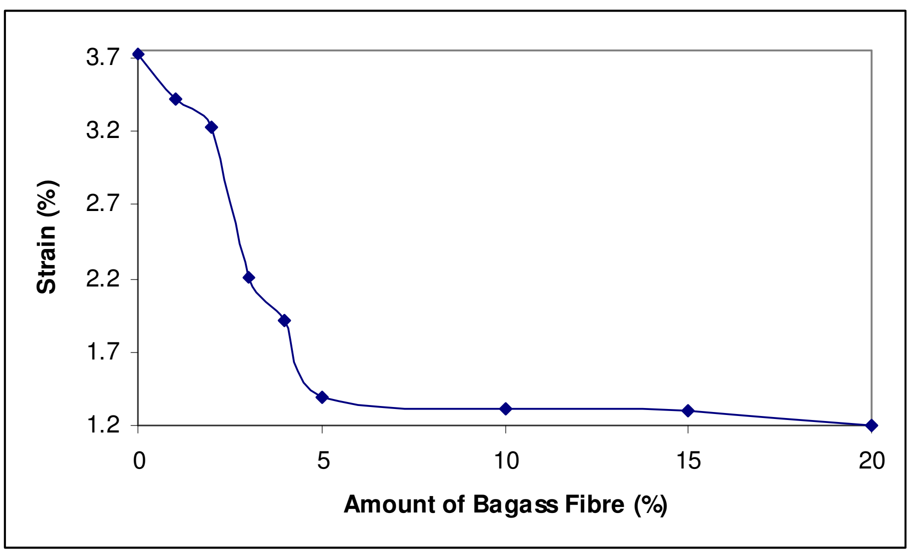

Figure 3. *Variation of the composite strain with the amount of bagass fibers.*

Figure 3 on the other hand shows that the elastic strain of the samples decreases with increase in the amount of bagass fibres incorporated. According to Callister [7], the greater the modulus, the stiffer the material, or the smaller the elastic strain that results from the application of a given stress; hence, the samples with greater quantity of Bagass fibre can be said to be stiffer. In other words, the addition of Bagass fibre improves the stiffness of polyester resin. This reveals that the bagass fibres are providing a reinforcement effect in polyester matrix composites [8, 9].

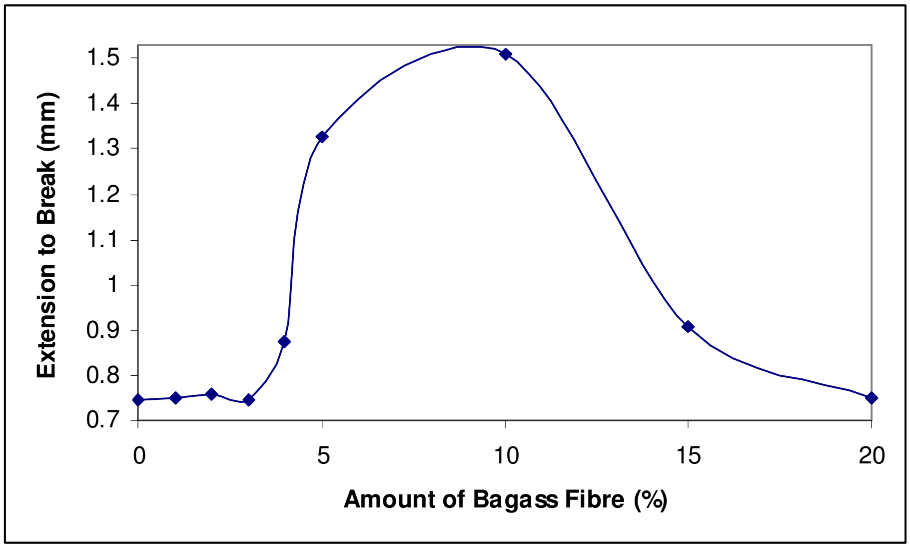

Figure 4. *Variation of the composite extension to break with the amount of bagass fibers.*

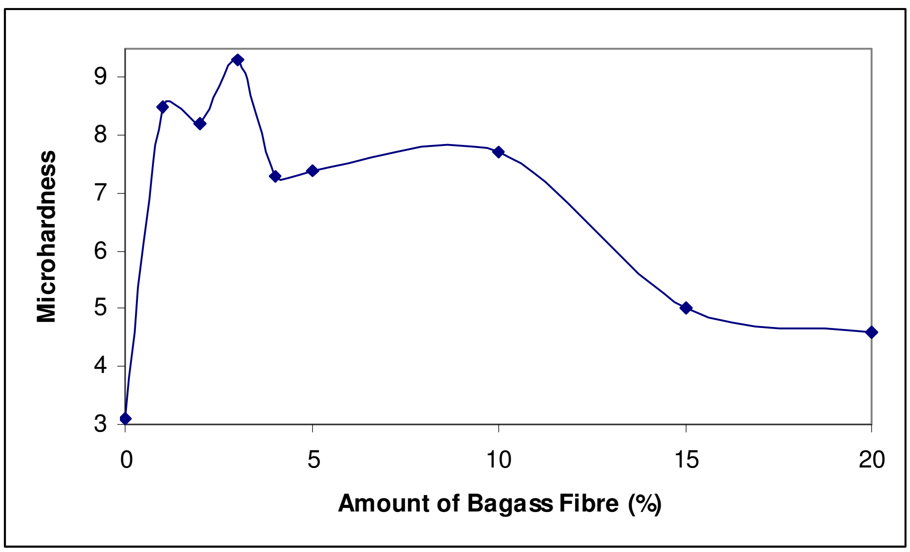

Figure 5. *Variation of the composite microhardness with the amount of bagass fibers.*

From Figure 5, the micro hardness of the materials increases in a fluctuating manner from 1% to 10% weight of fibre and reduces gradually from above 10% compare to the control(0%).The result implies that there is an increase in the hardness of the materials as the fibre is been added.

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Appendix

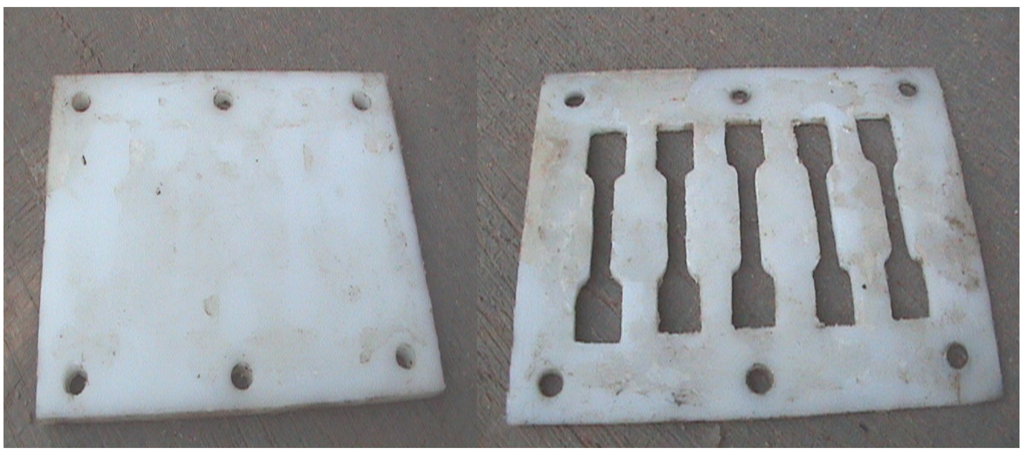
Table1: Tensile Test Results

SpecimenWith fibre content in wt%.	Maximum Load(N)	UltimateTensile Stress)(N/mm^2)	Modulus of elasticity(N/mm^2)	Strain (%)	Extension at break (mm)
0	478.88	10.01	381.30	3.72	0.74462
1	503.34	13.65	404.02	3.42	0.75012
2	579.44	14.61	422.39	3.23	0.75850

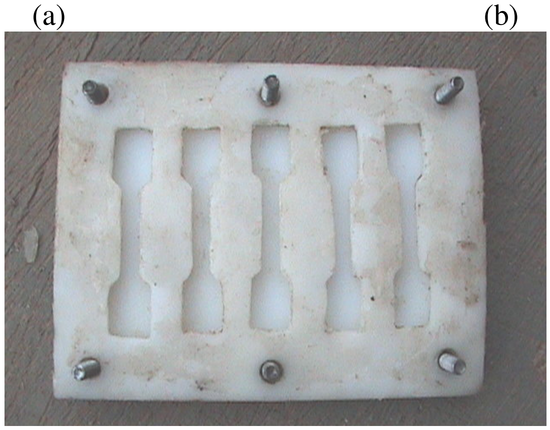
3	790.55	15.58	476.78	2.21	0.74462
4	860.76	17.84	512.34	1.92	0.87519
5	974.99	20.25	673.07	1.39	1.32512
10	1156.10	23.68	913.73	1.31	1.50844
15	371.36	12.15	746.00	1.20	0.90825
20	159.44	10.39	434.56	1.20	0.75012

Table 2: Data from the micro hardness tests

Sample	0%	1%	2%	3%	4%	5%	10%	15%	20%
1	3.3	9.0	9.6	7.5	5.9	6.2	6.8	4.2	4.0
2	3.7	7.9	8.4	10.3	5.9	6.0	6.0	5.8	4.3
3	1.8	8.4	7.2	6.9	8.6	8.8	10.2	5.8	5.0
4	3.5	8.3	8.5	10.9	8.9	8.8	8.5	5.6	4.5
5	3.4	8.9	7.5	11.1	7.3	7.2	7.1	3.6	5.2
Average	3.1	8.5	8.2	9.3	7.3	7.4	7.7	5.0	4.6



(a) (b)



(c)

Plate 1: *A set of mould used for making the tensile specimens. (a) and (b) are held together by bolt and nut as (c)*