Materials Today: Proceedings xxx (xxxx) xxx

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

Mechanical properties of Roystonea regia – Glass/epoxy composites with SiC particles

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ARTICLE INFO

Article history:
Available online xxxx

Keywords:
Roystonea regia fibres
Ceramic fillers
Glass fibres
Natural fibre composites

ABSTRACT

Extensive research has been made in the last decade for the development of natural fibre composites. This development provided more opportunities to engineers and researchers to come up with variety of natural fibre composites that exhibit excellent mechanical properties. In the present work, Roystonea regia natural fibre was used along with the glass fibre in the epoxy matrix. The mechanical properties such as tensile, flexural and hardness properties were determined at different fibre contents of the composites with or without the addition of silicon carbide ceramic fillers. The results reveal that, there is a significant improvement in tensile and hardness properties in the composites having equal weight percentage of royastanea regia and glass fibre without ceramic fillers, whereas flexural strength increased with the addition of ceramic fillers.
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Selection and peer-review under responsibility of the scientific committee of the 5th International Conference on Advanced Research in Mechanical, Materials and Manufacturing Engineering-2021

1. Introduction

Synthetic fibers reinforced with polymeric materials provide advantages of high stiffness and strength to weight ratio as compared to conventional construction materials. Despite these advantages, the widespread use of synthetic fiber reinforced polymer tends to decrease because of their high initial costs and their adverse effect on environmental issues [1]. Natural fibers exhibit many advantageous properties such as low-density materials, yielding a relatively lightweight composite with high specific properties. Therefore, the increased interest in using natural fibers as a substitute to conventional synthetic fibers in some applications has become one of the most concerns to study the potential of using natural fibers as reinforcement for polymer matrix composites [2,3]. The main disadvantage of natural fiber composites is its poor resistance to moisture absorption. Hence, the use of natural fiber alone in polymer matrix is inadequate in satisfactorily tackling all needs of fiber-reinforced composites. Due to this, a natural fiber can be combined with a synthetic fiber with the same matrix material provides the best advantage of properties of both natural and synthetic fibers. This idea results in a hybrid composite which gives better mechanical properties than natural fiber reinforced material [4,5]. Latha et al. [6] reported the effect of stacking sequence of mechanical properties of woven bamboo/glass fabric reinforced polymer hybrid composites. The results indicated that the properties of bamboo fiber reinforced composites were significantly improved by incorporation of glass fibers in polymer matrix composite.

Venkatesha et al. [7] studied the mechanical properties of bi-directional bamboo and E-glass fiber reinforced epoxy hybrid composites. Results revealed that composite laminate with 0/90° fiber orientation shows better tensile strength compared with other fiber orientations. Dalbehera et al. [8] studied the effect of cenosphere addition on the mechanical properties of jute-glass fiber hybrid epoxy composites. The mechanical properties are significantly influenced by addition of cenosphere up to 15 wt% and increases the tensile, flexural and interlaminar shear strength by 90.47%, 24.32% and 16.75%, respectively, in comparison to unfilled composite. Venkatesha et al. [9] studied the effect of cenosphere as particulate filler on mechanical behaviour of woven bamboo-glass hybrid composites. It was found that the mechanical properties are significantly influenced by addition of waste ceramic filler cenosphere up to 2 wt% and increases the mechanical properties in comparison to unfilled composite. Ramprasad et al. [10] bamboo strips were disintegrated into thin fiber bundles using a combina-

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https://doi.org/10.1016/j.matpr.2021.12.144
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Please cite this article as: V. Balaji and G. Goud, Mechanical properties of Roystonea regia – Glass/epoxy composites with SiC particles, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2021.12.144

tion of chemical and mechanical method. Hemanth et al. [11] produced polymer matrix composites from collagen fiber and epoxy matrix with varying volume fraction of fibers namely 10%, 20%, 30% and 40%. Test specimens prepared from the produced composite and subjected to pin on disc wear test to determine the wear rate for the collagen fiber reinforced polymer matrix composites to find the material's use as a bio-implant. In earlier studies, Venkatesha et al. [12,13] investigated the influence of stacking sequence of multi layered woven bamboo and glass fibers reinforced with epoxy matrix composites. The conclusions drawn based on the experimental results are discussed, and composite laminate with 0°/90° fiber orientation shows better mechanical properties. Ravi et al. [14] attempted to propose natural fibers in helmet manufacturing technology instead of synthetic fibers such as E-glass, carbon, Kevlar, etc., to enhance their mechanical properties. Yuvaraj et al. [15] developed a multilayer hybrid passive material for noise control in automobile by coupling of open pore polyurethane foam and closed pore aluminium metallic foam. Venkatesh et al. [16] selected the alternative Bio-coating material by using Aluminum Oxide, Egg and Seashell which are easily available in nature and economical. Selected Bio-active materials are used to protect the surface area of the Bio-implant. In the proposed study Roystonea regia fibers are being used as reinforcement. The extraction of fibers from Roystonea regia tree is very easy due to the low density and easy dissolve of the gums present in the sheath. The cost involved for this process is very less. Ripened foliage of Roystonea regia that falls on ground naturally are the fibre source. Roystonea regia trees can be found in California, Texas, Florida, Caribbean, South and Central America. Due to their grace and beauty, they are very popular as decorative trees. Particulate filled composites have been used extensively in various applications owing to their low production costs and the ease of fabrication. Besides, they are isotropic. Generally, fillers are used in polymers for a variety of reasons such as cost reduction, improved processing, improved strength density control, optical effects, thermal conductivity, electrical properties, magnetic properties, flame retardancy, improved hardness and wear resistance. Hard particulate fillers consisting of ceramic or metal particles and fibre-fillers made of glass are being used these days to improve the performance of polymer composites to a great extent [9]. The proposed research work arrives at investigating the mechanical properties of Roystonea regia/glass–epoxy composites with and without addition of silicon carbide (SiC) as fillers.

2. Materials and method

2.1. Specimen fabrication

The fibre of Roystonea regia was extracted from royal palm tree that are available locally. To prepare the hybrid composite, Roystonea regia is reinforced with glass fibre procured from the local supplier. Atul Limited, Gujarat, India supplied the epoxy resin (Lapox-12) and hardener K-6 which was used a matrix material. To get *Roystonea regia* fibre, the sheath obtained from Roystonea regia tree is separated from the leaf stem and leaves. The sheath is placed under the shade for three days. Later the sheath was immersed in water tank for about 25–30 days after which the sheath was rubbed by hand and rinsed with water to dissolve the greasy material and fine fibre was extracted. At the end to remove the surplus waste, the high volume of water was used to get the fibres. This followed by fibre drying for one week under the sun. For composite preparation, an average diameter of 0.25 mm Roystonea regia fibre was used. To remove surface moisture, both glass fibres and Roystonea regia were dried at 80 °C in an oven for 24 h. The form box was ready with the dimension of 300 × 300 × 3 mm. The two kinds of short strands were personally blended. Grid was ready by blending the hardener in epoxy. The ratio of epoxy and hardener was maintained at 10:1. Form box was stacked with suitable amounts of grid and filaments in irregular direction and earthenware fillers consistently in the shape any place important; the pressure was applied equally to accomplish a uniform thickness of 3 mm and relieved for 24 hr at room temperature. Three different types of samples are prepared. The composition and designation details are listed in Table 1. At the end, the plates of size 300mmx300mmx3mm made with royastenia regia, glass fibre reinforced with epoxy composites was prepared.

2.2. Tensile testing

Tensile test was finished with the assistance of Universal Testing Machine. It was led according to ASTM D 3039-76 with cross head speed of 10 mm/min. The dimensions of samples were 150 × 15 × 3 mm^3. Five samples were tested in each type and average values were listed.

2.3. Hardness testing (Shore D)

Hardness test was conducted on Shore D hardness tester as per ASTM-2240 standards. Five samples were tested in each type and average values were reported.

2.4. Flexural test

Flexural Test was done according to ASTM D 5943-96 guidelines at a cross head speed of 10 mm/min. The specimen dimensions were 100 × 15 × 3 mm^3. In each case, five samples were tested, and the average values were reported.

3. Results and discussion

The various mechanical and physical properties of *Roystonea regia* and glass fibres were shown in Table 2.

3.1. Hardness (Shore D)

The increase in glass fibre content increased the hardness values that are tabulated in Table 3. The thickness of glass fiber is a lot higher than the thickness of Roystonea regia fiber. The glass fibre density is much higher than the Roystonea regia fibre density. The hardness is thickness subordinate and will increment with expansion in thickness. Thus, expansion in glass fiber and SiC stacking would build the hardness of the crossover composite as shown in Fig. 1. Since the hardness and density are correlated, the loading of glass fibre and SiC increased the hardness of hybrid composites as density increases.

3.2. Tensile properties

Table 4 shows the % of extension at break with glass fiber stacking in mixture composites and its tensile strength. Figs. 2 and 3 shows the variation of % elongation & tensile strength of Roystonea regia-Glass Epoxy Composites. When compare the modules and strength of glass fibre with normal fibre, obviously for glass fibre it will be more. Hence the increase in % elongation at break and tensile strength is due to the increase in glass fibre loading in hybrid composites. In a hybrid composite, properties of the composite rely upon the Strength and % extension at break of the individual building up filaments. The expansion of silicon carbide diminished the elasticity. Expanded scattering of strands with

Table 1
Composition and designation of composites.

Sample Designation	Composition Details			
	Epoxy (wt.%)	Roystonea Regia Fiber (wt.%)	Glass Fiber (wt.%)	Ceramic SiC (wt.%)
A	100	0	0	0
B	80	20	0	0
C	80	10	10	0
D	80	10	5	5
E	80	5	5	10

Table 2
Mechanical and Physical properties of Roystonea regia-Glass Epoxy Composites.

Properties	Roystonea Regia Fiber	Glass Fiber
Density (g/cm^3)	0.825	2.14
Diameter (μm)	200–300	5–25
Tensile Strength (MPa)	263	2500
Young's Modulus (GPa)	21	55
% Elongation	4.012	4.5

Table 3
Hardness values of Roystonea regia-Glass Epoxy Composites.

Specimen	Hardness (Shore D)
A	77
B	7
C	83
D	82.5
E	83

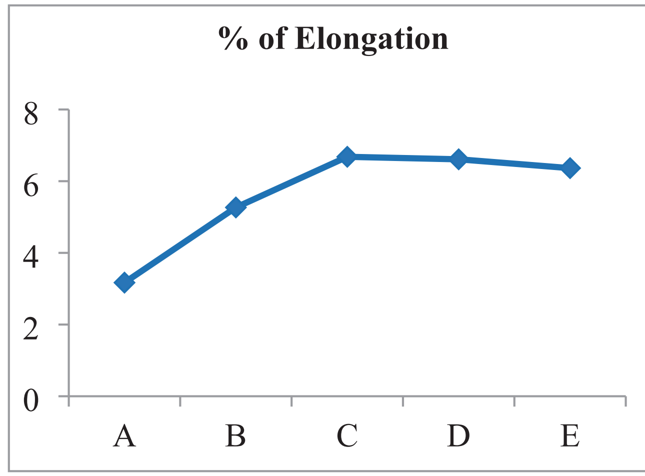

Fig. 2. Variation of % elongation of Roystonea regia-Glass Epoxy Composites.

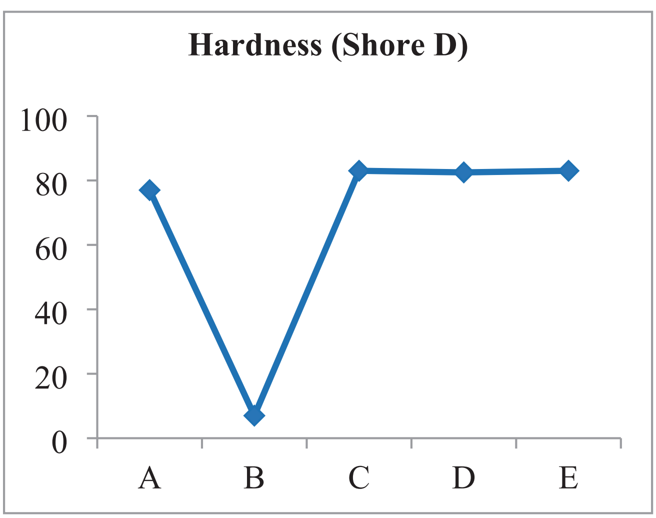

Fig. 1. Variation of hardness Values of Roystonea regia-Glass Epoxy Composites.

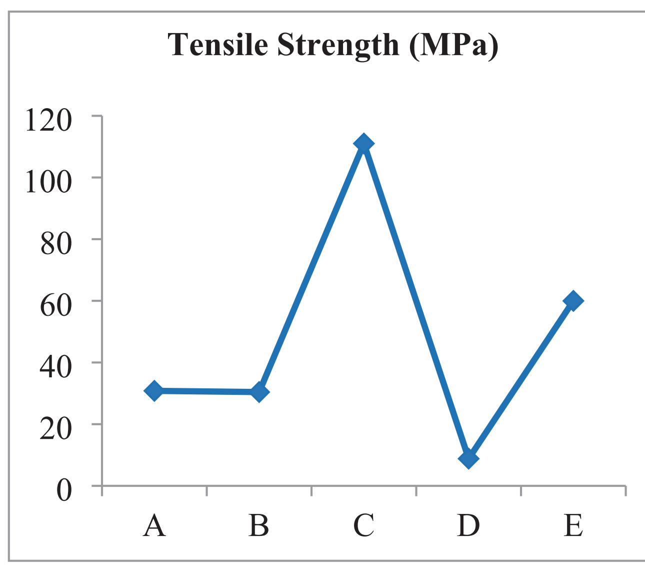

Fig. 3. Variation of Tensile Strength of Roystonea regia-Glass Epoxy Composites.

Table 4
Tensile Properties of Roystonea regia-Glass Epoxy Composites.

Specimen	% of Elongation	Tensile Strength (MPa)
A	3.17	30.80
B	5.267	30.42
C	6.68	111.02
D	6.61	8.82
E	6.364	59.98

expanded glass fiber stacking could be one more justification behind improved tensile properties.

3.3. Flexural properties

The increase in glass fibre weight percentage increases the flexural strength and flexural modulus of hybrid composites that are tabulated in Table 5. Fig. 4 shows the variation of flexural strength of Roystonea regia-Glass Epoxy Composites. With the expansion of glass fiber shear opposition of the mixture composite will expand which will limit shear failure. This is the reason for improved flexural properties. In flexural testing various mechanisms such as tension, compression, shearing take place simultaneously.

Table 5
Flexural Strength of Roystonea regia-Glass Epoxy Composites.

Specimen	Flexural Strength (MPa)
A	4.274
B	2.13
C	9.17
D	9.6
E	9.6

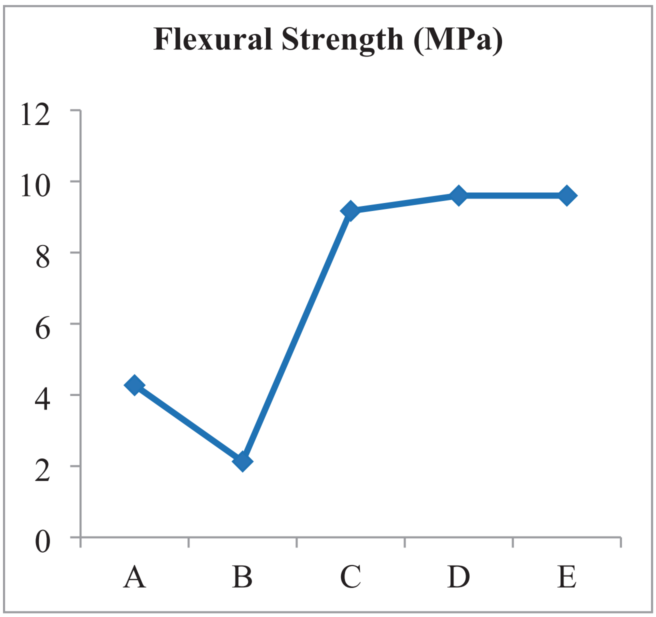

Fig. 4. Variation of Flexural Strength of Roystonea regia-Glass Epoxy Composites.

4. Conclusion

From this investigation, Roystonea regia fibre reinforced with glass fiber prompts an extensive expansion in tensile, flexural and hardness properties. The Roystonea regia and glass can be combined to produce hybrid composites. This increase in mechanical properties can be utilized for structural and automobile applications. There is a good scope of stuff in automotive, aerospace, wind energy, electrical, sports, domestic purpose, civil construction, medical chemical industries etc.

CRediT authorship contribution statement

V. Balaji: Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft. **Govardhan Goud:** Methodology, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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