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Experimental study on Mechanical properties on Lotus seed particle filled Carbon Fiber Reinforced Epoxy Composites

Manickavasaham G [1*], Dr. Balaguru P [2], Dr. Annamalai N [3]
[1*] Research scholar, Department of Mechanical Engineering, Annamalai University, Chidambaram, Tamil Nadu, India - 608002.
[2] Professor, Department of Mechanical Engineering, Annamalai University, Chidambaram, Tamil Nadu, India – 608002.
[3] Professor, Department of Mechanical Engineering, Mookambigai College of Engineering, Tamil Nadu, India – 622502.
vasaham.ji@gmail.com*

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ABSTRACT

An experimental study was conducted to determine the effect of adding filler material to carbon fiber composites. A manual layup process is used to create composites. All composites consist of fixed carbon fibers with a volume fraction of 5%. Various volume fractions (2, 4, 6, and 8%) of lotus seed filler are added to the composite. To ascertain the mechanical characteristics of composites, tensile and flexural tests are conducted. Testing and sample preparation were carried out in accordance with ASTM guidelines. As a result, it was found that the tensile strength increased at 6% filler loading and then tended to decrease when more filler was used.

Key words : Carbon fiber, Lotus seed powder, Epoxy, Mechanical properties.

1. INTRODUCTION

A composite material is one that is created from one or more constituent materials that have chemical or physical characteristics that are very different from one another. Composites are most often made by reinforcing fibers with a matrix resin. Reinforcements can be in the form of chopped or continuous fibers or particles and commonly used matrix materials are thermosetting matrix (epoxy, polyester, vinyl ester, BMI) and thermoplastic matrices (PEEK , PPS, polysulfone, thermoplastic polyamide). The current study is concentrated on using bio-filler (lotus seed particle) and carbon fiber to make composites. Maocheng Ji et al. [1] prepared a starch sisal fiber composite with various fillers. Based on test results, eggshell powder may replace talcum powder and $CaCO_3$. Wood charcoal reinforced composite was prepared by compacting unsaturated polyester matrix with 4, 8, 12, 16 & 20 wt% charcoal particles. The 4 wt% filler composite had better tensile properties than neat polyester composites [2]. S.Vigneshwaran et al. [3] Manufactured hybrid composites in polyester matrix with red mud as filler and sisal fiber as reinforcement. Testing on mechanical properties and water absorption revealed that adding more red mud had a negative impact. Numerous researchers have investigated numerous bio fillers, including rice husk, sawdust, calotropis gigantean stem powder, fish bone fragments, and groundnut shell ash [4-7 & 9]. Gaurav Agarwal et al [10] used five different wt% (0-20) silicon carbide on chopped glass fiber/epoxy composites and 10 wt% filler content composite shows superior mechanical properties. Singh V.K et al [11] found that addition of silica and banana fiber significantly affects elastic modulus.

2. MATERIALS AND METHODS

2.1 Materials

Lotus seeds are collected in Mayiladuthurai, Tamil Nadu, India. After being thoroughly cleaned with water, the seeds are exposed to direct sunlight for eight hours to dry. The seeds are then ground into a powder in a local grain mill and sieved to a 300-mesh size. Figure 1 shows the reinforcement – lotus flower (a), lotus seedpod (b), lotus seed (c), lotus seed filler (d) and carbon fiber mat (e). In this work, bidirectional continuous carbon fiber mat is used for reinforcement [5]. Epoxy resin grade LY556 and hardener grade HY951 were used in a ratio of 10:1 [7].

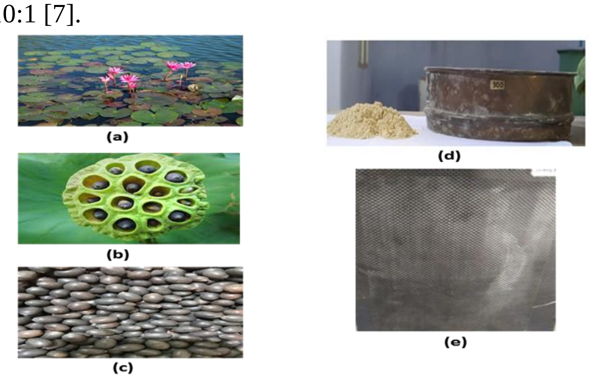

Figure 1: Preparation of Lotus seed filler (a) lotus flower, (b) lotus seedpod, (c) lotus seed, (d) lotus seed filler and (e) carbon fiber mat.

2.2 Fabrication of composite

The composite material is manufactured using hand-layup technique [9], lotus seed is utilized as natural filler, epoxy resin serves as the matrix, and carbon fiber mat serves as reinforcement. A 310 x 310 x 5 mm mild steel mold is used to create the composite. The natural filler and epoxy resin are combined with some simple swirling before being poured into the mould. Composite samples were prepared with different volume percentages of filler. A release agent (wax) allows the composite to be easily removed from the mold after curing [7]. If there are trapped air bubbles, remove them with a slide roller [3], close the mold and cure at room temperature for 24 hours. After curing, specimens are cut to dimensions suitable for mechanical testing according to ASTM standards. The compositions and names of the composites fabricated for this study are shown in Table 1.

Table 1: Specimen composition and designation

S.No.	Composites sample	Compositions
1.	S1	Epoxy (vol. 100%)
2.	S2	Carbon fiber (vol.5%) + Lotus seed filler (vol. 2%) + Epoxy (vol. 93%)
3.	S3	Carbon fiber (vol. 5%) + Lotus seed filler (vol. 4%) + Epoxy (vol. 91%)
4.	S4	Carbon fiber (vol. 5%) + Lotus seed filler (vol. 6%) + Epoxy (vol.89%)
5.	S5	Carbon fiber (vol. 5%) + Lotus seed filler (vol. 8%) + Epoxy (vol. 87%)

2.3 Mechanical tests

The composite's tensile strength was determined using ASTM: D638 [7]. The tests were carrying out on a universal testing machine (WDW 100) with a capacity of 50 KN and a crosshead speed: 1 mm/min and the results were analyzed. The tensile specimen and universal testing machine are shown in Figure 2a&b. Using a universal testing machine, a three-point bending test was carried out in accordance with the ASTM D790 standard to measure the flexural properties [8]. The bending test specimens are shown in Figure 2c.

3. RESULTS AND DISCUSSION

The tensile strength of various composite samples after testing is plotted in Figure 3. The tensile curve illustrates that, the good dispersion of lotus seed filler with the matrix increases the ultimate tensile strength of 59 MPa is obtained for the composite sample S4, on further increase in filler volume the corresponding ultimate tensile strength is decrease upto 37 MPa this indicate that there will be poor dispersion of filler with matrix. Flexural strength is one of the most important and often evaluated characteristics of composites in structural applications.

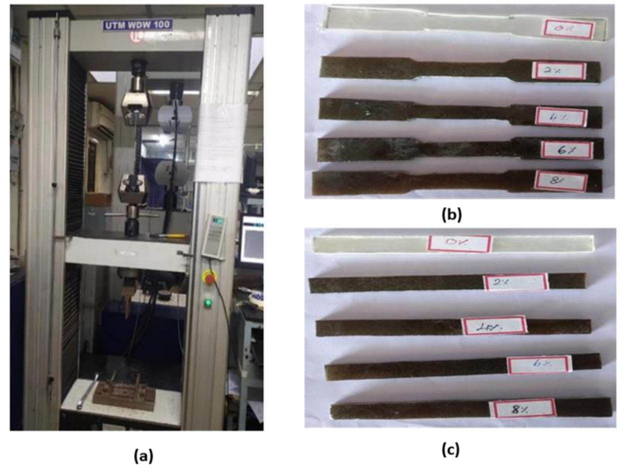

Figure 2: (a) universal testing machine, (b) tensile specimen & (c) flexural specimen

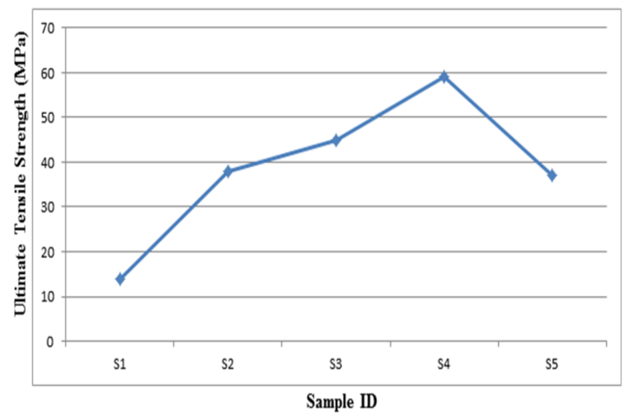

Figure 3: Tensile strength of lotus seed filler filled carbon fiber reinforced epoxy composite

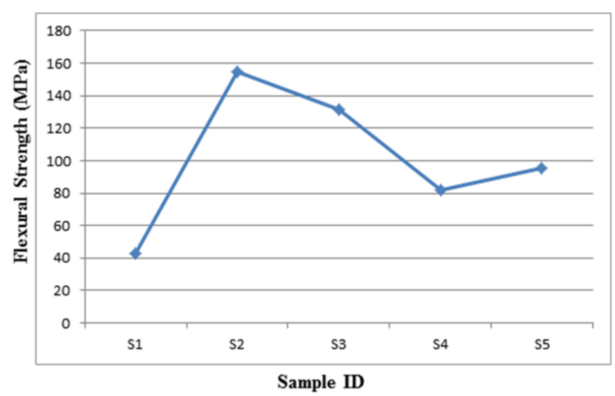

Figure 4: Flexural strength of lotus seed filler filled carbon fiber reinforced epoxy composite

Figure 4 shows the flexural strength of different volume fraction of lotus seed filler-reinforced composites. Composite sample S2 has a maximum bending strength of 154.67 MPa. A detailed comparison of the mechanical properties of lotus seed filler/carbon fiber/epoxy-based composites is shown in Table 2.

Table 2: Detailed contrast of mechanical properties of lotus seed filler/carbon fiber/epoxy-based composite with other fiber composites and fillers

Reinforcement/filler/matrix	Manufacturing process	Tensile strength (MPa)	Flexural strength (MPa)	Reference
Carbon fiber / lotus seed filler / epoxy	Hand lay-up	14 - 59	42.63 – 154.67	Present work
Sisal / corn starch / talcum powder / ethylene glycol & glycerol	Hot pressing	2.7	-	[1]
Sisal / corn starch / $CaCO_3$ powder / ethylene glycol & glycerol	Hot pressing	3.2	-	[1]
Sisal / corn starch / egg shell powder / ethylene glycol & glycerol	Hot pressing	3.3	-	[1]
Jute / wood charcoal / polyester	Hand lay-up	19 - 33.4	-	[2]
Industrial waste-based red mud / Sisal fiber / Polyester	Compression moulding	23 - 44	-	[3]
Banana fiber / groundnut shell ash / epoxy	Hand lay-up	10.21 - 12.02	-	[4]
Phoenix Pusilla / carbon / fishbone filler / epoxy	Hand lay-up	22.97 -114.67	101.25 - 286.88	[5]
Indian mallow fiber / sawdust / Polyester	Compression moulding	65	275	[6]
Calotropis gigantea stem powder / glass fiber / jute fiber / epoxy	Hand lay-up	35.04 - 48.73	115.34 - 195.19	[7]
Glass fabric / Epoxy / graphite	Hand lay-up and Hot press	355.8	475.22	[8]
Glass fabric / Epoxy / Silicon carbide	Hand lay-up and Hot press	404.2	455.84	[8]
E glass fiber / Banana chopped / Polyester	Hand lay-up	42 - 45	81 - 89	[9]
E glass fiber / Rice husk / Polyester	Hand lay-up	40 - 44	77 - 85	[9]
Silicon carbide / Chopped glass fiber / Epoxy	-	184 - 254	55 - 87	[10]
Banana / Silica powder / epoxy	-	27.618	-	[11]

4. CONCLUSION

This study successfully examines the mechanical characteristics of carbon fiber reinforced epoxy composites containing lotus seed fillers. The following points can be derived from the observation results:

- The sample S4 shows superior results in ultimate tensile strength, which are relatively higher than calotropis gigantea stem powder, groundnut shell ash and fishbone particle.
- The flexural strength decreases from 154.67 MPa to 42.63 MPa as the filler content increases from 2% to 8%.
- Interfacial bonding and stress concentration are key parameters in composites that affect mechanical properties.

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