IOP Conf. Series: Materials Science and Engineering **376** (2018) 012097 doi:10.1088/1757-899X/376/1/012097

Study on the effect of varying volume fraction on mechanical properties of coconut shell powder reinforced epoxy matrix composites

Mohan Kumar[1*], Abhishek Bala[2], Prithviraj M[2], Raghavendra[2] and VinayPrasad[2]

[1]Faculty of Mechanical Engineering, Mangalore Institute of Technology & Engineering, Moodabidri

[2]Undergraduates of Mechanical Engineering, Srinivas School of Engineering, Mangalore

* Corresponding Author: haimohanji@gmail.com

Abstract. Coconut shell powder reinforced epoxy matrix composite is made of coconut shell powder, epoxy resin, and hardener. The tensile and compression tests of composites conducted at three different volume fractions of coconut shell particulates. The experimental results reveal that tensile strength of the composites increased with the decrease of the coconut shell particulate content, whereas compressive strength increases with the increase of the coconut shell powder.
Keywords:Coconut shell particulate, Epoxy resin, Hardener, UTM, Tensile strength, Compression strength

1. Introduction

Composite materials are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. For example, concrete consists of crushed stones or limestone, cement, sand, and water. The composition occurs on a microscopic scale; new material is then called an alloy for metals or a polymer for plastics. A composite material is composed of reinforcement (fibres, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). This reinforcement is very tough and different shapes can be obtained. They are much preferred because they are less expensive, stronger, and lighter [1]. Nowadays, naturally obtained particles reinforced composites have considerable potential to replace conventional materials like metals, plastics, and wood in structural and non-structural applications.

Ramesh M and Nijanthan S investigated the mechanical properties such as tensile, flexural and impact strengths of these composites of kenaf and glass fibres with two different fibre orientations of 0◦ and 90◦. From the experiment, it was observed that the composites with the 0◦ fibre orientation can withstand the maximum tensile strength of 49.27 MPa, flexural strength of 164.35 MPa, and impact strength of 6 J. Whereas, the composites with the 90◦ fibre orientation hold the maximum tensile strength of 69.86 MPa, flexural strength of 162.566 MPa and impact strength of 6.66 J [2].

R. S. Wani and R. R. Shitole prepared composites with unidirectional bamboo fiber reinforced with epoxy resin, and conducted tensile test on the 10kN universal testing machine and results were obtained. For the volume fraction of the fiber of 20%, the tensile strength of bamboo reinforced epoxy composite was found to be 26.417 MPa at 2.4 kN [3].
Jute, Coir, and Bamboo natural fiber composites are considered to have potential use as a reinforcing material in epoxy polymer-based composites because of their good strength, stiffness etc. In the study conducted by Tanwer A.K, mechanical properties for these natural fiber composites were evaluated. Here, these natural fibers are the fiber reinforcement and epoxy polymer resin as a matrix material. Composite were prepared with different longitudinal (Unidirectional) natural fiber reinforced with the epoxy-based polymer. Tensile and compression tests were conducted and found that the tensile strength of jute, bamboo, coconut coir fiber composites are 9.155, 13.05, 3.208 Mpa respectively and compression strength is 31.28, 35.42, 25.41 Mpa respectively [4].
Mechanical Properties of Pineapple Leaf Fibre-Reinforced Polyester Composites was carried out by Devi. L.U and found that tensile strength is 17, 40 and 52.9 Mpa respectively for 10 %, 20%, and 30% volume fractions of pineapple fibre [5].
Focus on natural fiber reinforced polymer matrix composites are growing rapidly in terms of industrial applications and in the field of research. Plants, such as coconut shell, flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, wood etc. are used as natural fiber. Advantageous are availability, biodegradable, completely or partially recyclable, renewable, cost-effective, eco-friendly, and less weight. Therefore, they are used extensively in many manufacturing industries. These are also used in transportation (automobiles, railway coaches, aerospace), military applications, construction industries, packaging, consumer products [6].
Recently naturally available fibers like jute, hemp, flax, have been considered for reinforcing plastic as they need less energy to grow and also it supports to the farmer to rely on agriculture. Since they are lightweight they are extensively used in automotive industry. Ford model U hybrid-electric car and Mercedes Benz A class are already started using this type of naturally available composites in their model [7]. Currently, Motorcar industries such as Rolls-Royce and Jaguar are using specifically wood for panels and interior components [8].

2. Materials Used

The materials used in the preparation of composites are coconut shell powder, epoxy, and hardener, of which the details are explained in the following paragraphs.

2.*1 Coconut Shell Particulate*

Coconut shell particulate is made from versatile part of the coconut. The shell is inorganic in nature which is available profusely and procuring them is cost-effective [9]. It has good durability characteristics high toughness and abrasion resistant properties. The shell is similar to hard woods. The coconut shell composite material offers strength and rigidity, eco-friendly, renewable and abundant in nature.

2.2 Epoxy Resin and Hardener

The epoxy resin used is LAPOX B 11. It is a general purpose BIS – A-based liquid epoxy resin with medium viscosity. The density of LAPOX B 11 at 25^0C is 1.15 g/cc (kg/l) [10]. Hardener suitable for LAPOX B 11 is MSDS H – 140. The density of the hardener at 25^0C is 1.015 g/cc (kg/ltr).

3. Experimental Procedure

3.1 Sample preparation

Initially, coconut shell powder of <150 micron grain size was obtained using mechanical siever. Coconut shell powder was weighed and dried in a microwave oven for 30 seconds. The epoxy resin and hardener are collected in the proportion of 2:1 by volume. The weighed resin is stirred using mechanical stirrer, simultaneously the coconut shell particles are added to it. Stirring of mixtures is continued along with heating at 50^0C for about 10 minutes. After getting the uniform mixture of shell and resin matrix, hardener was added and stirred for 3 minutes. Then the mixture is poured into the mould cavity. Before pouring the mixture into mould cavity the releasing agent is applied on the walls of the mould to enable the easy removal of the sample after drying. The samples were dried in the mould for 20 hours at room temperature. Then it is removed from the mould and dried in an oven at 50^0C for 4 hours. This procedure is done for the different volume fraction of coconut shell powder.

Fig.1 and fig.2 illustrates mixing of the epoxy resin, coconut shell powder, hardener by stirrer and then mixtures are poured into mould cavity.

Figure 1. Illustrates mixing of the epoxy resin, coconut shell powder, and hardener

Figure 2. Mixture poured into mould cavity

3.2 Tests conducted

To study the mechanical behavior tensile test and compression test are conducted. The tensile testing of the specimens was conducted to know the breaking (ultimate tensile strength) strength of the composite under tensile load. The composite was loaded till its breaking point and the load v/s displacement curve for each coconut shell powder volume fraction is drawn. Compression test is similar to tension test, expect the loading is in opposite direction i.e., compressive loads, which produce crushing action. The load v/s displacement curves for each coconut shell powder volume fraction are drawn as shown in figure 3 to figure 8.

The tensile test specimen was prepared according to ASTM D 3039 standard. Tensile and compression the tests were carried out in Universal Testing Machine of 40 Ton capacity. It is used for ascertaining the strength and deformation of all kinds of materials, such Plastics, wood, composite materials. All tests were conducted at Raghavendra Spectro Metallurgical Laboratory, Bangalore.

4. Results and discussion

4.1. Tensile test results

Using the data obtained from tensile test load versus displacement graphs are drawn for the different volume fractions as depicted in the following figures. The tensile tests are conducted for two samples of each volume fraction.

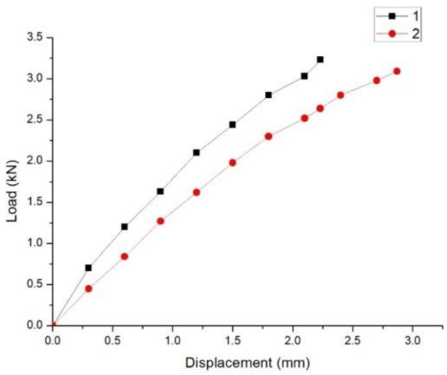

Figure 3. Load versus displacement curve for 10% volume fraction curve

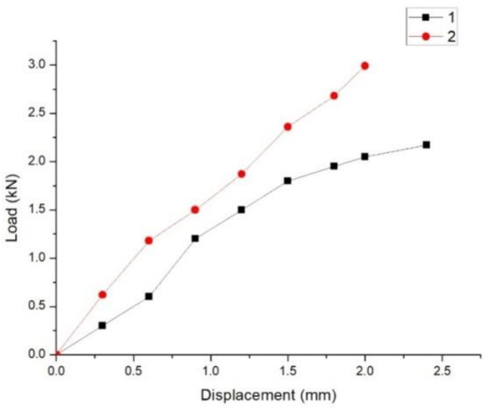

Figure 4. Load versus displacement curve for 20% volume fraction curve

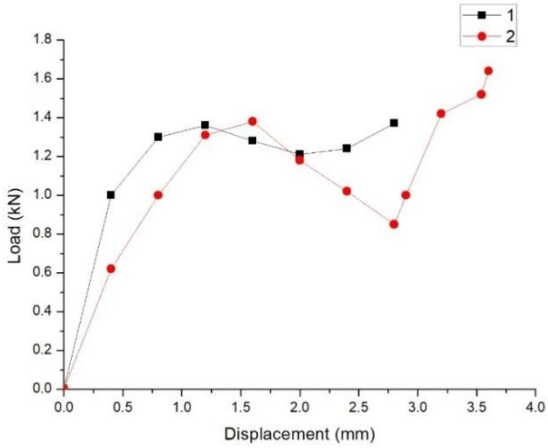

Figure 5. Load versus displacement curve for 30% volume fraction curve

From the figure 3, Sample 1 - It can be observed that the maximum load taken by it is 3.09 kN and deformation obtained is 2.87 mm. Tensile Strength is found to be 46 MPa. The results of Sample 2 indicate that maximum load taken by it is 3.25 kN and deformation obtained is 2.25mm. Tensile Strength is 44MPa. Therefore the average Tensile strength of 10% volume fraction composite is 45 MPa.
From the figure 4, for Sample 1, the ultimate load taken is 2.2 kN and deformation obtained is 2.5 mm. Tensile Strength is 39.12 MPa. For Sample 2 it can be observed that maximum load taken by it is 2.99kN and the net deformation obtained is1.99 mm. This gives a Tensile strength of 39 MPa. Hence the average Tensile strength of 20% volume fraction composite is 39 MPa.
The results of 30% volume fraction composite indicate that the maximum load carried by the Sample 1at failure is 1.4 kN and deformation observed is 2.75 mm. Tensile Strength is 25.5 MPa. Sample 2 would carry a maximum load of 1.64 kN and deformation obtained is 3.66 mm. Tensile Strength is 29 MPa. So the average Tensile strength of 30% volume fraction composite is 27.25 MPa.

4.2. Compression test results
From the Compression test results, Load versus Displacement graphs are plotted for three different volume fractions of coconut shell powder as shown in the following figures. The compression tests are conducted for two samples in each case.

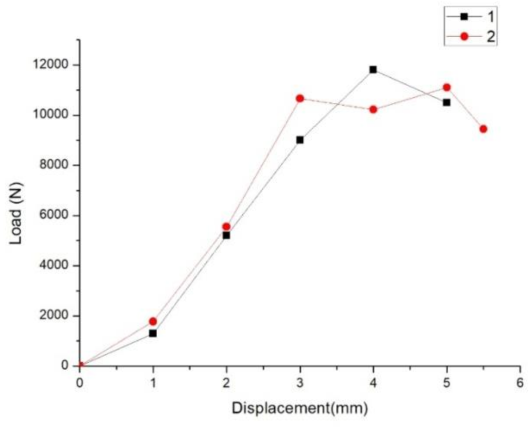

Figure 6. Load versus displacement curve for 10% volume fraction curve

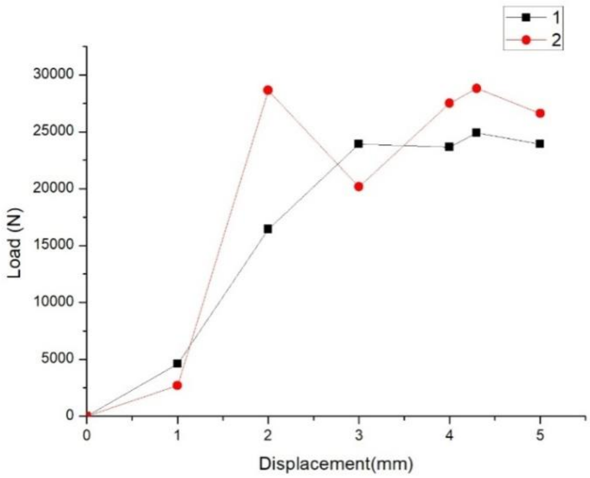

Figure 7. Load versus displacement curve for 20% volume fraction curve

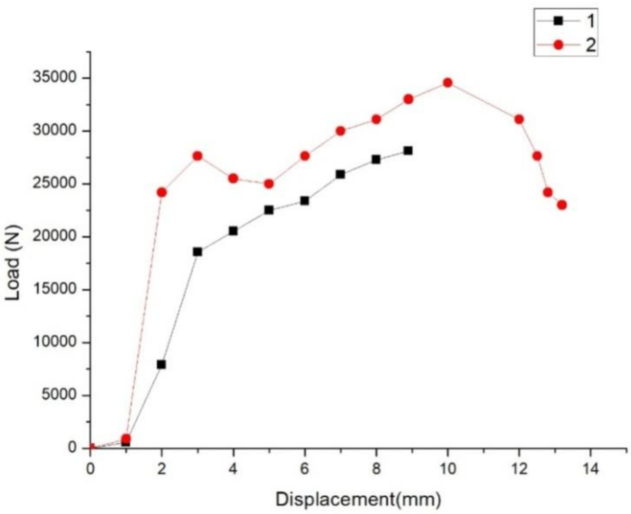

Figure 8. Load versus displacement curve for 30% volume fraction curve

From the figure 6, for Sample 1 the maximum load observed at fracture is 12 kN and deformation obtained was 5 mm. Compression Strength is 27 MPa. For Sample 2the ultimate load taken is 11 kN and deformation obtained is 5.5 mm. Compression Strength is 24.2 MPa. The average Compression Strength of 10% volume fraction composite is 25.6 MPa.
The load at failure for Sample 1of 20% volume fraction is observed to be 25kN and deformation obtained is 5mm. Compression Strength is 58MPa. For Sample 2 the maximum load taken at fracture is 28.8 kN and deformation obtained is 5 mm. Compression Strength is 64.68 MPa. Therefore the average Compression Strength of 20% volume fraction is 61.34 MPa.
From the figure 8, Sample 1 indicated the maximum load taken by it is 27.5 kN and deformation obtained is 9 mm. Compression Strength is 73 MPa. For Sample 2 the ultimate compressive load taken by it is 34.65 kN and deformation obtained was 11.4 mm. Compression Strength is 90.5 MPa. This yields an average Compression Strength of 81.75 MPa for 30% volume fraction composite.

5. Conclusion

Tensile and compressive properties of epoxy composites reinforced with coconut particulate have been studied and results are discussed. The tensile strength obtained for 10%, 20%, 30% volume fraction of coconut shell powder composite are 45, 39, and 27.25 MPa respectively and compression strength are

25.6, 61.34, 81.75 Mpa. The tensile strength is found to be increasing with the decrease of the coconut shell particulate content and compressive strength increases with the increase of the coconut shell particulate content. And the final values obtained are at par with jute, bamboo, coconut coir, pineapple and bamboo reinforced composite matrix. Using coconut shell powder is more convenient compared to other natural composite materials because it is present abundantly in nature and easy to prepare.

6. References

[1] Rahul Reddy Nagavally , (2016) "Composite Materials - History, Types, Fabrication Techniques, Advantages, and Applications" , International Journal of Management and Applied Science (IJMAS) , pp. 87-92, Volume-4,Issue-3, Spl. Iss-2
[2] Ramesh M, Nijanthan S, Bull Mater Sci., Vol. 39, No. 1, February 2016, pp. 147–157, Mechanical property analysis ofkenaf–glass fibre reinforced polymer composites using finite element analysis.
[3] R. S. Wani, R. R. Shitole, "Tensile Testing of Bamboo Fiber Reinforced Epoxy Composite'', e-ISSN: 2278-1684,p-ISSN: 2320-334X PP. 07-11
[4] Tanwer A.K., American International Journal of Research in Science, Technology, Engineering & Mathematics, 8(1), September- November, 2014, pp. 41-45
[5] Devi. L.U., Bhagawan S.S. and Thomas S., Mechanical Properties of Pineapple Leaf Fiber-Reinforced Polyester Composites, J. Appl. Polym. Sci., 64(9), 1739-1748 (1997)
[6] March G, ''Next step for automotive material'', Mater today, (2003) 36 – 43
[7] Michael F. Ashby, Kara Johnson, ''Materials and Design: The Art and Science of Material Selection in Product Design'' (2002)
[8] T. Prakash, "Processing and Characterization of Natural Fiber Reinforced Polymer Composites," Bachelor's Thesis, National Institute of Technology, Rourkela, 2009.
[9] Alok, S., Savita, S., Aditya, K., "Study of mechanical properties and absorption behavior of coconut shell powder-epoxy composites". International Journal of Materials Science and Applications. Vol. 2 (2013), No. 5, pp. 157-161.
[10] Lee, H. and Neville, K. Handbook of Epoxy Resins, Classical Re-issue, McGraw-Hill, New York, 1982.