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Fabrication and Evaluation of Nano Carbon Reinforced Polymer Composites

M. Melkin Jebasingh[1] and G.Antony Wilbert singh[2]

*[1]Assistant Professor Department of Mechanical Engg,
Dr.Sivanthi Aditanar College of Engineering-Tiruchendur
Mobile No:+919543424621.
[2]Assistant Professor Department of Mechanical Engg,
Dr.Sivanthi Aditanar College of Engineering-Tiruchendur
Mobile No:+919629255264*
[1]melkin.mech@gmail.com
[2]mech.antony88@gmail.com

Abstract

In this study the suitability of using nano carbon as a new raw material for thermoset composites is investigated. The study evaluates the mechanical properties of nano carbon composites. The nano carbon from Biomass (waste material of Zea Mays) is used as a reinforcement material with the matrix resin for preparing the composites. The composites developed by hand molding technique are varied with weight percentage of nano carbon (0.1%, 0.2%, 0.3%, and 0.4% up to 1.5%). The developed natural nano carbon reinforced polymer composites were characterized by mechanical properties. The composites reinforced with 0.5 & 0.6 wt% of nano carbon particles have shown better mechanical strength. The properties of sourghum based nano carbon/Epoxy composites are greater than that of epoxy resin matrix composites even for a little amount of carbon reinforcement.

Keywords— Nano carbon**,** Polymers, Mechanical Properties**.**

1. INTRODUCTION

In the recent years the researchers focused their attention to utilize the natural resources as a reinforcement material in composites. This natural reinforcement material is abundantly available in most part of the world. The applications of such as natural organic fillers have low cost, low density, biodegradability, recyclability and environment friendly [1]. The efficiency of reinforcement depends on several parameters such as filler size, filler shape, filler dispersion, surface area, surface reactivity, filler structure and bonding quality between fillers and the matrix [2]. Agricultural by products are emerging as new and inexpensive materials with commercial viability and environmental acceptability. Among this kind of materials, lignocelluloses fillers are considered to be used as fillers of thermoplastic polymers [3]. Many attempts have been made to produce activated carbon from agricultural wastes such as coconut shells, sugarcane and sorghum pith [4]. A large quantity of sorghum pith produced remains unused in field and the disposal of such agricultural wastes is a hectic task. Recent years one of the most developments areas of the Nano technology in Materials research is a polymer nano composite. [5] During the last years the effects of different types of fillers such as natural activated carbon compounds on mechanical properties have been studied, in research of improvements on its physical and mechanical properties. Moreover the conversion of agricultural wastes into valuable end products may help to increase production efficiency as well as to reduce solid wastes disposal problems [6]. Furthermore, the temperature range used in chemical activation is lower in comparison to that used in physical activation method. Many researches have been conducted on the applications of various types of nanocomposite for different engineering components. It is due to the increase of surface contact area which allows more interlinking between the nano particles and the matrix [7]. Hence, the mechanical properties of the nanocomposites can also be greatly enhanced. Epoxy resin of commercial grade has been used to prepare composites due to its significant importance in many of the commercial applications. [8].

The main objective of this paper is to study the mechanical properties of activated nano carbon reinforced polymer composites by varying wt% of nano carbon particles. The thermoset resin, general polymer resin is used as a matrix polymer and the nano carbon prepared from biomass is used as reinforcement. The bio mass is collected from the local sources, cut in to small pieces and then pulverized. The biomass is carbonized by acid method. This carbon is converted into nano particles by ball milling method. The composite plates are fabricated using hand layup method by mixing various concentrations of nano with epoxy matrix(0.1% to 1.5%). The above experimental details are discussed elaborately in section 2. The thickness of the fabricated composites is maintained at 3 mm. the strength property relationship of the composites is evaluated in section 3. The discussion of results is elaborated in section 4. The conclusions are arrived at section 5.

2. EXPERIMENTAL DETAILS

2.1Materials

Epoxy resin was used as a matrix material and it was purchased from a local source. Reinforcement material, activated nano carbon was extracted from the seed removed corn cob stocks collected from agriculture waste found in rural agricultural sources in Tuticorin and Tirunelveli districts of Tamilnadu.

(a) (b) (c)

Fig 1. a. Seed removed Corn cob Stock, **b.** Pulverized form of corn stock **c.** Dry carbon Powders

2.2 Physical properties of corn cob:

The physical properties (moisture content, particle size, bulk density and porosity) of a given biomass material such as corn cobs greatly influence the design and operation of thermochemical conversion systems. High moisture content decreases the heating value of fuel, which in turn reduces the conversion efficiency as a large amount of energy would be used for the initial drying step during the conversion processes. The particle size distribution affects the flowability, heating, diffusion and rate of reaction. The bulk density affects the economics of collection, transportation and storage as well as feeding the material into the thermochemical conversion system. Porosity affects the interstitial airflow velocity and the heat and mass transfer conditions and ultimately influences reaction parameters such as heat conductivity, burning rate, conversion efficiency and emissions.

Moisture content (%)	Average particle size (mm)	Bulk density (kgm^{-3})	Porosity
6.38	0.56	282.38	67.93

2.3 Preparation of nano Carbon

The seed removed corn cob stocks [Fig.1a] of the Zea mays plant crops were collected from various field. The corn cob stocks were washed and dried at atmospheric temperature. Then it was cut into small pieces [Fig.1b], pulverized and dried at atmospheric temperature. The carbon powders were extracted from pulverized corn stocks by acid method. In acid method the organic waste material was heated with concentrated sulphuric acid in the range of 120^0-300^0 C to produce pseudo activated carbon.

Then carbon particles produced by this method was washed with water. The residue after washing shows adsorption and ion exchange properties when used in wet state and loses its adsorption properties when it is used in dry condition.

Generally the organic wastes which are lignin rich contain carboxylic and phenolic functional groups. By acid method organic materials are carbonized with the help of sulphuric acid. Sulphuric groups were created in the waste material through sulphonation reaction which then exhibits ion exchange with cations present in the solution. Washing removes acid residues in the carbon powder. The residue is dried in atmospheric condition at 3hrs. The dried carbon powder sample [Fig.1.c].is converted into nano particles by using ball milling machine. Particle sizes are measured using particle size reader. The size distribution report by intensity method revealed an average particle diameter as 231 nm and width as 16.33nm.

2.4 Preparation of Specimen

The epoxy resin was used as a matrix material. It was economical due to its excellent process ability and good cross-linking tendency as well as mechanical properties when cured. The nano carbon reinforced polymer matrix composites were fabricated using hand molding method. For proper chemical reaction, polyamine was used as a hardener for quick setting of the resin. The epoxy resin and the hardener were taken in the ratio of 10:1. It was thoroughly stirred using the stirrer to obtain a homogeneousness mixture.Then nano carbon in different wt% of matrix material was added to the epoxy resin. Then this matrix mixture was transferred to mold to prepare a panel of 160 X 180 mm [fig.3(a)]. It was allowed to cure for about 3hrs at room temperature. At the end of molding process 3mm thickness composite plates were produced. The finished specimen was shown in the Fig.3(b). The composites reinforced with different wt% (0.1%,0.2%,0.3%,0.4%, 0.5%,0.8%,0.9%,1.0%,1.1%,1.2%,1.3%,1.4%,1.5%) of nano carbon were prepared for testing.

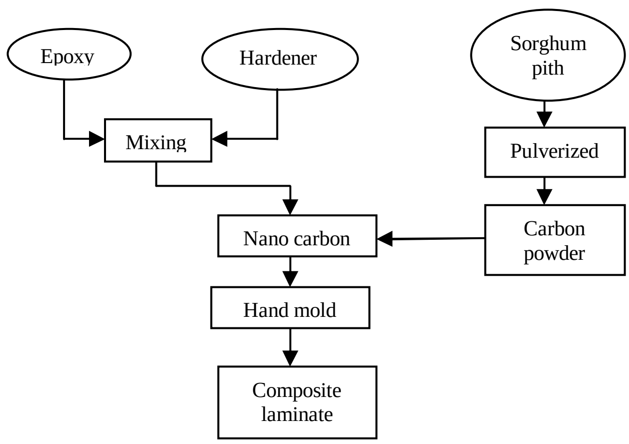

Fig.2 Fabrication of the nano carbon composites

Fig.3 (a) Hand molding setup

Fig (b) (3.b) NCRP Composite sheet.

3. MECHANICAL TESTING
3.1 Tensile Test
The tensile test specimens of required dimensions were cut from the fabricated composite sheet. The tensile test specimen was prepared according to the dimension, gauge length and cross-head speed of 2mm/min found in ASTM D3039. The specimen was tested in a computerized universal testing machine. All the test results were taken from the average of three tested samples. The test results are plotted as shown in table 1.

Table 1.Tensile properties of nano-composites.

Sl.No	Nano Carbon Wt %	Yield elongation (mm)	Ultimate yield (N)	Break elongation (mm)	Break force (N)	Tensile strength at yield (N/mm^2)	Tensile strength at break (N/mm^2)	Modulus of rigidity (N/mm^2)
1.	0	1.6	2109	2.1	1500	35	25	3937
2.	0.1	1.8	2353	2.3	1700	39	29.3	3900
3.	0.2	1.9	2505	2.3	1800	42	30	3978
4.	0.3	1.7	2603	2.2	2100	43.3	35	4050
5.	0.4	2	2698	2.5	2300	45	38.3	4071
6.	**0.5**	**2.1**	**2852**	**2.7**	**2400**	**47.5**	**40**	**4584**
7.	**0.6**	**1.9**	**2802**	**2.3**	**2350**	**46.6**	**39.1**	**4414**
8.	0.7	2.1	2648	2.4	2100	43.3	35	3711
9.	0.8	2.2	2501	2.4	2200	41.6	36.6	3403
10.	0.9	2	2197	2.3	2000	36.6	33.3	3294
11.	1.0	1.8	2104	2.1	1800	35	30	3500
12.	1.1	1.8	2296	2.1	1800	38.3	30	3830
13.	1.5	1.9	2198	2.3	1900	36.6	31.6	3467

3.2 Compression Test
Compression test is carried out on a polyplaster machine with a cross head speed of 2mm/min according to the standard ASTM D638.Three samples were taken for each composition and the results are averaged. Compression and deflection load of the composites are given in table 2.

Table 2. Compressive strength of composites.

Material	Compressive Strength(Kg/cm2)
Pure resin (Epoxy)	49.13
0.5 wt % of nano carbon composite	62.3
0.6 wt % of nano carbon composite	60.56

3.3 Flexural test:

Flexural test is carried out on a polyplaster machine with a cross head speed of 2mm/min according to the standard ASTM D622. Three samples were taken for each composition and the results are averaged. Flexural strength of the composites are given in table 3.

Table 3. Flexural strength of composites.

Material	Flexural Strength (N/mm^2)
Pure resin (Epoxy)	18.30
0.5 wt % of nano carbon composite	25.04
0.6 wt % of nano carbon composite	24.95

3.4 Impact test:

In impact test the strength of the samples were measured using an Izod impact testing machine based on ASTM D256. The test specimen being supported as a simply supported beam is strike broken by a single swing of the pendulum, with a scale plate reading the energy loss. Three samples were taken for each composition and the results are averaged. The measure values are given in table4.

Table 4. Impact strength of composites.

Material	Impact Strength (Joules)
Pure resin (Epoxy)	0.2
0.5 wt % of nano carbon composite	0.6
0.6 wt % of nano carbon composite	0.48

3.5 Hardness test:

Hardness test of the sample was measured using Brinell hardness testing machine. An indentation is made by applying a controlled test force for a specific dwell time and the size of the indent is measured optically to derive out the hardness number. Four indentations were taken for each composition at varied location of the sample and the results are averaged. The measure values are given in table 5.

Table 5. Hardness property of composites.

Material	BHN
Pure resin (Epoxy)	47
0.5 wt % of nano carbon composite	51.12
0.6 wt % of nano carbon composite	50.24

4. RESULTS AND DISCUSSION
4.1 Tensile Properties
Composites of pure resin and nano composites with 0.1 to 1.5 wt% of nano carbon particulate in the epoxy resin were prepared and tested. It was observed that the addition of Nano carbon in the epoxy matrix has improved the tensile properties significantly. The addition of 0.5 wt % of Nano carbon increases the inter molecules bonding strength of matrix and the tensile strength of the polymer matrix 1482 N/mm^2 and thereafter the further addition of the nano particle decreases the tensile strength of the polymer composites. From Fig.4, it was estimated that the maximum weight percent of nano carbon particle content to improve the tensile strength of the polymer composite was 0.5wt%.

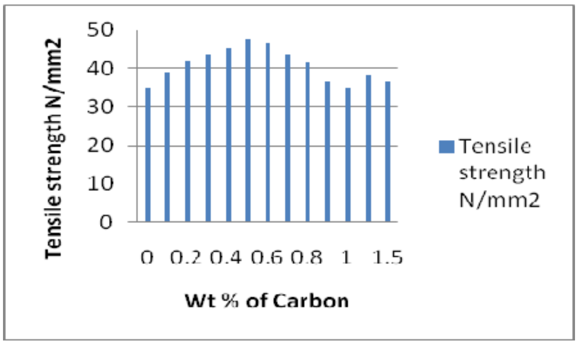

Fig.4 Effect of nano carbon weight % on the Tensile strength

The tensile strength of the nano carbon reinforced polymer (NCRP) with 0.5 and 0.6wt % of Carbon was increased compared to the tensile properties of pure resin value. The values of tensile properties of pure resin and composites are given in Table1.

4.2 Compressive property
The compressive test results shows the different nano carbon weight % such as 0.5 and 0.6 by weight are in range 62.3 Kg/sq.cm and 60.56 Kg/sq.cm. The maximum compressive strength was obtained in 0.5% wt of nano composites.

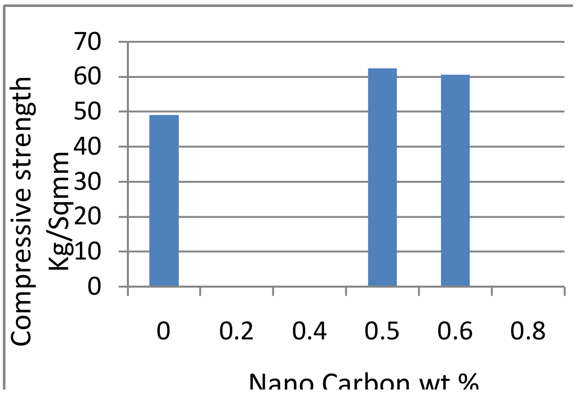

Fig.4 Effect of nano carbon weight % on the compressive strength

4.3 Flexural test:
The flexural test results depicts the different nano carbon weight % such as 0.5 and 0.6 by weight are in range 25.04 N/mm^2 and 24.95 N/mm^2. The maximum flexural strength was obtained in 0.5% wt of nano composites.

4.4 Impact test:
The maximum impact strength value was obtained in the 0.5 wt % of nano composites and has a value of 0.6J. This impact value leads to the higher toughness properties of the material.

4.5 Hardness test:
The maximum impact strength value was obtained in the 0.5 wt % of nano composites and has a value of 51.12BHN.

5. CONCLUSIONS

1. This study focused on the evaluation of nano carbon reinforced polymer (NCRP) in which the Tensile strength, has been studied.
2. It was observed that the composite with 0.5 & 0.6wt % of nano carbon shows the better result with tensile strengths and modulus of elasticity.
3. The response of the reinforced composite to he various types of loading like tensile, compression, flexural, hardness and impact was encouraging according to the nature of the composite. It was understood that the reinforcement of nano carbon composite was newer material with general superior properties and load carrying capacity.
4. They can also be potential candidate for the partial replacement of high cost glass/kevelar fibers to make polymer composites used for low cost applications in areas like pollution, biodegradeable, non abrasive during machining etc.

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