Effect of Carbonized Coconut Shell Particles on Mechanical Properties of Bio-Based Composite

Shakuntala Ojha¹, G. Raghavendra² and S.K. Acharya³

Department of Mechanical Engineering, ¹Talla Padmavathi College of Engineering, Warangal, Telengana, India; ²NIT Warangal, Warangal, Telengana, India and ³NIT Rourkela, 769008, Odisha, India

Abstract: Carbon black particles are fabricated from coconut shells by pyrolysis process at 400°C carbonization temperature and used as reinforcement in epoxy composites. The biocomposites were characterized for mechanical and morphological properties. Results showed that due to increases in carbonization temperature the carbon percentage increases in carbon black particles. Tensile strength, tensile modulus, flexural and flexural modulus tests were performed at different filler loading. The results indicated that mechanical properties increase as the carbonization temperature increases and also as filler loading increased when compared with the neat epoxy. From proximate analysis it is clearly observed that carbon percentage increases due to pyrolytic decomposition of raw shell particles and a good interfacial bonding was observed between filler and polymer from morphological analysis.

Keywords: Coconut shell, Carbon black, Tensile test, EDS.

1. INTRODUCTION

The exploits of elevated performance, advanced composites for engineering applications, carbon has been one of the magnificent elements which have revolutionized material science in recent years. The production of carbon black is relatively expensive because of its dependence on dwindling supplies of crude oil [1]. Many researchers have evaluated an alternative for developing carbon from bio waste in a new way for the next carbon black generation [2].

Carbon black can be derived from varied biomass waste products such as bamboo, jute, cotton, flax, which are carbonaceous in nature and received raised attention as alternative fillers because of their low cost and abundance. These biomass rich in lignocellulosic fibers can produce biocarbon (carbon black) after carbonization because they have high fixed carbon content [3]. On the other hand the overwhelming majority of carbon black finds use for waste water treatment and heavy metal removal, the separation technology by its adsorption capabilities has been known as carbon great utilization for many years [4]. A more economical approach is to incorporate bio waste carbon black fillers in to composite in the form of particulate fillers to replace the use of synthetic fillers likes aramid and glass. Also, the high potential of carbon gives an impact in the thermoset polymer industry, growing rapidly in civil and construction areas. The properties of carbon used in the composites mostly depend on the origin, processing conditions, and chemical treatments.

Many studies have been carried out on carbon black from biomass as filler in composite such as bamboo, oil palm shell [5], rice husk [6] and coconut shell [7], wood apple shell [8]. Among the different natural fibers, coconut shell (Cocos nucifera) appears to be promising material because of the high hardness and toughness. The shell of the coconut is one part of the waste after removing the husk, which is very hard lignocellulosic and can be converted into carbon black. Coconut shell has the potential to be used as a filler material in polymer composite due to its high carbon content. Recent developments on various applications of polymer composites are well documented in many literatures, however the fundamental and applied studies of these materials are still of keen interest to many researchers. Epoxy resin is a widely used polymer matrix for advanced composites where good stiffness, dimensional stability and chemical resistance are required [5].

In the present investigation, carbon black filler from coconut shell was evaluated to be used as filler material for the epoxy composites. The effects of carbon black fillers on the mechanical properties and morphology of composites were investigated. In addition the characterization of the biomass based carbon black filler were also determined.

2. EXPERIMENTAL DETAILS

2.1. Materials and Methods

The coconut shells used in the present investigation are initially washed with water to remove the impurities and dried in an oven at 110°C for 24 hours to remove excess water content and moisture. The dried shells
are converted to fine powder using a ball milling process for 24 hours and followed a sieve analysis to measure a particle size. The shell particles chosen for the experiments are in the range of 1 to 212 µm. The polymer that is used to fabricate the particulates composite is epoxy resin, LY 556 (Bisphenol-A-Diglycidyl Ether) having density 1.2 g/cm³ at 25°C and it is mixed with curing agent i.e. hardener HY-951 [NN0 (2-aminoethylethane-1, 2-diamin)] with density 0.99 g/cm³.

2.2. Processing of Carbon Black Preparation

The raw coconut shell particles were loaded on a ceramic boat which was placed inside a muffle furnace and heated up to desired carbonization temperature i.e. 400°C at a heating rate of 5°C/min and held for at least 2h at the carbonization temperature under inert atmosphere. To avoid oxidation, which could subsequently cause ashing, an inert environment was created by the passage of Nitrogen gas at the time of carbonizing process. After completion of carbonization a soaking time of 1h was given after the furnace was switched off. The produced carbon black is shown in Figure 1.

![Carbon black coconut shell particles](image)

Figure 1: Carbon black coconut shell particles.

2.3. Characterization of Coconut Shell Particles

Proximate analysis is one of the most important characterization methods to analyse the biofiber. It provides information on moisture, ash, volatile matter and fixed carbon content of the material in case of dry base or weight base. In the present case the proximate analysis of shell particles has been carried out following the ASTM standards E-871, E-1755, E-872; for moisture (at 110°C), ash (at 715°C) and volatile matter (at 925°C) using muffle furnace respectively. Fixed carbon is usually determined by subtracting the sum of the first three values that is moisture, ash, and volatile matter (weight percent from 100 percent). So, it is very important for economic reasons to know the moisture and ash contents of the material.

\[
\text{Fixed carbon (\%) } = 100 - (\text{Moisture, } \% + \text{Ash, } \% + \text{Volatile matter, } \%)
\]  

(1)

<table>
<thead>
<tr>
<th>Coconut</th>
<th>Proximate Analysis (wt.%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FC</td>
</tr>
<tr>
<td>Raw shell particles</td>
<td>17.54</td>
</tr>
<tr>
<td>Carbon black particles (400°C)</td>
<td>52.72</td>
</tr>
</tbody>
</table>

2.4. Composite Fabrication

The composites were prepared by hand layup technique with raw and carbon black as filler in polymer composites using four different compositions (5, 10, 15 and 20 wt.%). A wooden mold of (150x60x5) mm³ is used for manufacturing the composite. A calculated amount of epoxy resin and hardener (ratio of 10:1 by weight) was thoroughly mixed and a proper stirring is done with mechanical stirrer for uniform mixing of raw shell particulates. The above mixture was poured in to the mould. Care has been taken to avoid formation of air bubbles and loss during manufacturing. 30 kg load also applied for 24h for proper curing at room temperature. In the similar manner carbon black composite was also prepared. Test specimens of suitable dimensions are cut according to ASTM standard with a diamond cutter for further analysis and studies.

2.5. Mechanical Properties of Composite

In this study, the mechanical properties, which include tensile and flexural strengths of raw and carbon black coconut shell composite, were investigated. Both tensile and flexural test has been conducted on a universal testing machine INSTRON H10KS as per ASTM D3039-76 and ASTM D790 standard. To evaluate the value of flexural strength (FS), the short beam shear tests (generally it is 3-point bend test) are performed on the samples at room temperature. The five specimens per test condition was carried out for accuracy of testing the polymer matrix composite materials.

2.6. Elemental Analysis

The elemental composition of coconut shell particles is determined by Energy Dispersive Spectroscopy (EDS). The EDS was obtained in a “spot mode” in which beam is focused on a single area selected within the field of view.

2.7. Scanning Electron Microscope

Scanning electron microscopy (SEM) was used to monitor the fracture surface of the tensile and flexural specimens after mechanical test of each sample. SEM
analysis was performed using Nova Nano SEM 450 at an accelerating voltage of 15kV. The fractured surface of specimens composites were sputtered with a layer of gold/palladium before the measurements.

3. RESULT AND DISCUSSION

From Table 1 it is clearly observed that the raw coconut shell particles having 17.54% carbon but after carbonization of the shell particles at 400°C, carbon percentage significantly increases up to 52.72%. This is only due to the removal of some non-carbon elements from the raw particles at carbonization stage. These parameters are essential to determine the level of fillers in the polymer, which effectively affect the properties of final product.

3.1. Elemental Analysis (EDS)

Figure 2 and 3 shows the inspection spectra of coconut shell particulate surface. The surface of coconut shell raw particulates exhibit spectra containing mainly carbon, oxygen, zirconium, silicon and small amount of calcium. However these elements are slowly removed from raw coconut shell particulates by para-lytic decomposition of shell particulates at 400°C carbonization temperatures. The presents of hard element like SiO$_2$ and Al$_2$O$_3$, the raw wood apple shell powder can be used as particulate reinforcement in various polymer matrixes.

3.2. Tensile Properties

Figures 4 show the tensile behavior of the composites based on raw and carbon black as filler. From the result it is clearly observed that the tensile strength increased as filler loading increased from 5 to 20 wt.% in raw composite. However after addition of carbon black particles with neat epoxy, the strength of the composite drastically increases as compared to neat epoxy and raw composite. In general the maximum tensile strength 46.39 MPa was recorded of carbon black composite at 15 wt.% filler loading. It might be attributed to better dispersion of carbon black in the matrix, better wettability and interfacial bonding. The strength decreased beyond 15 wt.% loading due to increase in the particle concentration of the filler material, thereby increasing agglomeration, which makes composite material brittle.

3.3. Flexural properties

On the other hand the result of flexural strength of raw and carbon black coconut shell composite at different filler loading are presented in Figure 5. In general, the graph of flexural strength shows an increasing
Effect of Carbonized Coconut Shell Particles

Journal of Mineral Metal and Material Engineering, 2016, Vol. 2

9

trend as the carbon black filler loading percentage is increased. This trend could be because of better surface adhesion between epoxy and carbon black filler. Hence the maximum flexural strength 79.48 MPa was obtained at 20 wt.% filler loading.

3.4. Morphology of Composites

The SEM image of 20wt% raw coconut shell filler composites is shown in Figure 6a. There is no sigh of voids on the surface still slipping of surface took place. This might have occurred due to formation of internal cracks which are not visible on the surface. Figure 6b, which shows the morphology of the specimen for 15wt% carbon black (400°C) reinforced composite derived from coconut shell. The micrographs were taken from the tensile fracture composites in order to analyze the effect of carbon black loading and the adhesion of filler-matrix interphase of the composites. It is clearly observed that a good interfacial bonding between carbon black fillers and matrix materials are formed.

4. CONCLUSION

- Proximate analysis of coconut shell particles reveals that due to carbonization effect the fixed carbon content was increased from 17.54 % to 52.72%.

- The effect of carbon black coconut shell particles as a filler in epoxy composites on mechanical properties showed that the tensile strength increased at 15 wt. % carbon black content and decreased at 20 wt. % compared with neat epoxy matrix due to the low surface interaction and nonuniformity of the stress transfer from carbon epoxy matrix to carbon black filler at the composite. However flexural strength decreased at 15 wt.%, it may be happen due to agglomeration or void present in the composite.

- Morphological study has shown the effect of carbon black loading on the adhesion of filler-matrix interphase on the fracture surface in epoxy based carbon black composite.

REFERENCES


Received on 07-11-2015  Accepted on 19-11-2015  Published on 12-01-2016

© 2016 Ojha et al.; Licensee Synchro Publisher.
This is an open access article licensed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/3.0/), which permits unrestricted, non-commercial use, distribution and reproduction in any medium, provided the work is properly cited.