Study On Mechanical Behavior Of Groundnut Shell Fiber Reinforced Polymer Metal Matrix Composites

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ABSTRACT

This paper examines the mechanical properties of metal matrix composites based on groundnut shell fiber. Fiber-reinforced polymer composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus. The fiber which serves as a reinforcement in reinforced plastics may be synthetic or natural. Past studies show that only synthetic fibers such as glass, carbon etc., have been used in fiber-reinforced plastics. Although glass and other synthetic fiber-reinforced plastics possess high specific strength, their fields of application are very limited because of their inherent higher cost of production. In this connection, an investigation has been carried out to make use of coir, a natural fiber abundantly available in India. Natural fibers are not only strong and lightweight but also relatively very cheap.
The present work describes the mechanical properties and development of a new set of natural fiber based polymer composites consisting of groundnut coir as reinforcement and epoxy resin. Experiments are carried out to study the effect of fiber length on mechanical behavior of these epoxy based polymer composites. In the present work, coir composites are developed and their mechanical properties are evaluated. Also a step forwarded to use the agricultural waste technically and enhance the properties of several existing material which can be more useful and can have advanced properties than the existing form. Finally the composites were made by varying the percentage of groundnut shell from 0% to 6%. The specimens were tested before and after the heat treatment and data of hardness values for all composites in both conditions were acquired from Rockwell hardness test. The results emphasized the increasing hardness value and reducing density of composites. The main objective is to compare the hardness and density of prepared composites from alloy from. Also comparison was made before and after the heat treatment. The detailed test results and observations are discussed sequentially in the paper.

Keywords: Groundnut shell particles, Physical and Mechanical properties.

1. INTRODUCTION

The advantage of composite materials over conventional materials stem largely from their higher specific strength, stiffness and fatigue characteristics, which enables structural design to be more versatile. By definition, composite materials consist of two or more constituents with physically separable phases [1, 2]. However, only when the composite phase materials have notably different physical properties it is recognized as being a composite material.
Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. Significantly, constituents of the composites retain their individual, physical and chemical properties; yet together they produce a combination of qualities which individual constituents would be incapable of producing alone. The reinforcement may be platelets, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material.

1.1 Types of Composites

For the sake of simplicity, however, composites can be grouped into categories based on the nature of the matrix each type possesses [3]. Methods of fabrication also vary according to physical and chemical properties of the matrices and reinforcing fibers.
(a) Metal Matrix Composites (MMCs)

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Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminium, magnesium and titanium.
The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide.

(b) Ceramic Matrix Composites (CMCs)
Ceramic matrix composites have ceramic matrix such as alumina, calcium, aluminum silicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced with silicon carbide fibers. These composites offer the same high temperature tolerance of super alloys but without such a high density. The brittle nature of ceramics makes composite fabrication difficult. Usually most CMC production procedures involve starting materials in powder form. There are four classes of ceramics matrices: glass (easy to fabricate because of low softening temperatures, include borosilicate and aluminum silicates), conventional ceramics (silicon carbide, silicon nitride, aluminum oxide and zirconium oxide are fully crystalline), cement and concreted carbon components.

(c) Polymer Matrix Composites (PMCs)
The most common advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low density of the constituents the polymer composites often show excellent specific properties.

1.2 Groundnut

Groundnut botanically known as Arachis hypogeal belongs to Leguminosae family. India is the second largest producer of groundnut after China. In India, groundnut is the largest oilseed in terms of production and accounted for about 7.5 million tons during 2009-10. A complete seed of Groundnut is called as pod and outer layer of Groundnut is called shell. Brian George et.al. [4] Investigated the groundnut shell fiber characterization. Average length of the groundnut shell fibers was found to be 38mm and 0.25mm diameter. Average tenacity of groundnut shell fiber is of 1.06 g/den. Also, average strain of the fibers was 7.45 % and average modulus 25.3 g/den. The selected groundnut shells are used in the present study. Clean and dried groundnut shells are initially washed with water to remove the sand and other impurities. The washed shells are then chemically treated with 10 % NaoH solution for 1 hour and later washed with distilled water. Subsequently, the shells were dried at room temperature for 24 hours. The dried shells were ground and particles were sieved through 600µm BS sieve. The similar procedure was followed by the authors [5 to 7] for the preparation of material.

1.3 Chemical Composition of Groundnut Shell

Lignocelluloses fibers are constituted by three main components: hemicelluloses, cellulose and lignin, which are known to present very complex structure. Cellulose, which is the main fraction of the fibers, is a semi crystalline polysaccharide made up of D-glucosidic bonds. A large amount of hydroxyl groups in cellulose gives hydrophilic properties to the natural fibers. Hemicellulose is strongly bound to the cellulose fibrils, presumably by hydrogen bonds. It consists of polysaccharides of comparatively low molecular weight built up from hexoses, pentoses and uronic acid residues. Lignin acts as the cementing agent in fiber, binding the cellulose fibers together [8]. Chemical composition of groundnut shell is compared with the composition of selected species. The hemi cellulose content of the fiber was found to be 18.7%, cellulose 35.7%, lignin 30.2% and Ash content 5.9% [9]. Table 1 compares the chemical compositions of groundnut shell with some other important natural fibers.

The hemi cellulose content of groundnut shell is greater than Sisal. The lignin content of groundnut shell fiber is much greater than that of coconut coir, bamboo, hemp, and Kenaf and sisal fibers.

Species	Cellulose, wt%	Hemicellulose, wt%	Lignin, wt%	Ash, wt%	Reference
Coconut coir	47.7	25.9	17.8	0.8	[10]
Sisal	63-64	12	10-14	--	[10]
Ground nut shell	35.7	18.7	30.2	5.9	[9]
Rice husk	31.3	24.3	14.3	23.5	[11]
Bagasse	40-46	24.5-29	12.5-20	1.5-2.4	[12]
Hemp	70.2-74.4	17.9-22.4	3.7-5.7	--	[13]
Kenaf	31-39	21.5	15-19	--	[13]

Table 1: Chemical composition of some natural resources

2. MATERIAL AND METHOD

The experimental procedures followed for their mechanical characterization. The raw materials used in this work are

a) Groundnut ash
b) Epoxy resin
c) Hardener

2.1 Specimen preparation

The fabrication of the various composite materials is carried out through the hand lay-up technique. A groundnut fiber is reinforced with Epoxy LY 556 resin, chemically belonging to the 'epoxide' family is used as the matrix material. Its common name is Bisphenol A Diglycidyl Ether. The low temperature curing epoxy resin (Araldite LY 556) and corresponding hardener (HY951) are mixed in a ratio of 10:1 by weight as recommended. The epoxy resin and the hardener are supplied by Ciba Geigy India Ltd. The Groundnut ash is collected from rural areas of Andhra Pradesh, India. Five different types of composites have been fabricated with five different Groundnut fiber lengths such as 5mm, 20mm, 25mm, 30mm and 35mm.Each composite consisting of 30% of fiber and 70% of epoxy resin. The designations of these composites are given in Table 3.1. The mix is stirred manually to disperse the fibers in the matrix. The cast of each composite is cured under a load of about 50 kg for 24 hours before it removed from the mould. Then this cast is post cured in the air for another 24 hours after removing out of the mould. Specimens of suitable dimension are cut using a diamond cutter for mechanical testing. Utmost care has been taken to maintain uniformity and homogeneity of the composite.

Composites	Compositions
C1	Epoxy (70wt %) +Coir Fiber (fiber length 5mm) (30wt %)
C2	Epoxy (70wt %) +Coir Fiber (fiber length 20mm) (30wt %)
C3	Epoxy (70wt %) +Coir Fiber (fiber length 25mm) (30wt %)
C4	Epoxy (70wt %) +Coir Fiber (fiber length 30mm) (30wt %)
C5	Epoxy (70wt %) +Coir Fiber (fiber length 35mm) (30wt %)

Table 2: Designation of Composites

2.2 Mechanical Testing

After fabrication the test specimens were subjected to various mechanical tests as per ASTM standards. The tensile test and three-point flexural tests of composites were carried out using Instron 1195. The tensile test is generally performed on flat specimens. A uniaxial load is applied through both the ends. The ASTM standard test method for tensile properties of fiber resin composites has the designation D 3039-76. Micro-hardness measurement is done using a Leitz micro-hardness tester. A diamond indenter, in the form of a right pyramid with a square base and an angle 1360 between opposite faces, is forced into the material under a load F. The two diagonals X and Y of the indentation left on the surface of the material after removal of the load are measured and their arithmetic mean L is calculated. In the present study, the load considered F = 24.54N. Low velocity instrumented impact tests are carried out on composite specimens. The tests are done as per ASTM D 256 using an impact tester.

3. RESULTS AND DISCUSSION

This present study the mechanical properties of the coir fiber reinforced epoxy composites prepared for this present investigation. Details of processing of these composites and the tests conducted on them have been described in the previous. The results of various characterization tests are reported here.

This includes evaluation of tensile strength, flexural strength, impact strength and micro-hardness has been studied and discussed. The interpretation of the results and the comparison among various composite samples are also prepared.

3.1 Mechanical Characteristics of Composites

The characterization of the composites reveals that the fiber length is having significant effect on the mechanical properties of composites. The properties of the composites with different fiber lengths under this investigation are presented in Table 3

Composites	Hardness (Hv)	Tensile strength (MPa)	Tensile modulus (GPa)	Flexural strength (MPa)	Impact energy (KJ/m2)
C1	12	2.53	0.827	20.32	14
C2	9.2	8.64	1.326	24.36	14.5
C3	16	13.08	1.906	28.36	15.5
C4	21	14.56	2.356	31.63	16
C5	24	16.08	2.807	35.06	17.5

Table 3 Mechanical properties of the composites

3.2 Effect of Fiber length on Micro-hardness

The measured hardness values of all the five composites are given in Table 4.1. It can be seen that the hardness is decreasing with the increase in fiber length up to 20mm. However further increase in fiber length increases the micro hardness value.

3.3 Effect of Fiber length on Tensile Properties

The test results for tensile strengths and tensile modulus are shown in Table 4.1. It is seen that the tensile strength of the composite increases with increase in fiber length. There can be two reasons for this increase in the strength properties of these composites compared. One possibility is that the chemical reaction at the interface between the filler particles and the matrix may be too strong to transfer the tensile. From Table 4.1 it is clear that with the increase in fiber length the tensile moduli of the coir fiber reinforced epoxy composites increases gradually.

3.4 Effect of Fiber length on Flexural Strength

The test results for flexural strengths are shown in Table 4.1. It is interesting to note that flexural strength increases with increase in fiber length.

3.5 Effect of Fiber length on Impact Strength

The impact energy values of different composites recorded during the impact tests are given in Table 4.1. It shows that the resistance to impact loading of groundnut coir fiber reinforced epoxy composites improves with increase in fiber length. High strain rates or impact loads may be expected in many engineering applications of composite materials. The suitability of a composite for such applications should therefore be determined not only by usual design parameters, but by its impact or energy absorbing properties.A new type of metal matrix composite was formed namely GSA composites and a new reinforcement material was introduced called “Groundnut shell ash (GSA)”.

Rockwell hardness test was carried out for all four Al-GSA composites made with 0%, 2%, 4% and 6% of GSA. Magnesium contributed constantly with 0.6% of composite weight. Hardness result showed the variation of hardness from pure aluminium to prepared composites. Specimen made of pure aluminium result is very poor hardness whereas Al-GSA composites made with 2% GSA composition showed a considerable increment of 5 HRB. In a same way 4% GSA composite and 6% GSA composite showed the increment of 8 HRB and 12 HRB respectively in compare with pure aluminium specimen.

Along with the hardness increment density difference was also observed, where density decreases with increment percentage of Groundnut shell ash content. The variation in density was recorded from 2.6 g/cc to 1.95 g/cc for 0% GSA content and 6% GSA content composites respectively. With the plotted graph it is expected that the density of composites can be brought to 1.65 g/cc with the composition of 15% groundnut shell ash content.

The effect of temperature on hardest Al-GSA was observed by applying heat treatment process at constant temperature of 180 ˚C with the six variation of soaking period. The soaking time was given 3, 6, 9, 12, 15, 17 hours respectively for the six specimens of same composite. Hardness results was observed in such a way that, hardness increase up to 12 hours of soaking period and then decrease drastically from there. The reason for this decreasing is observed in microscope. Up to 12 hours cohesion was too strong between the matrix and reinforcement and in later stage bond start becoming weak which resulted decrease in hardness. Finally it is concluded that these composites can't be exposed to the temperature for a long period. Long period of heating may lead failure of Al-GSA composites.

% of GSA content	HRB
0	64.23
2	68.86
4	72.05
6	74.68

Table 4: Hardness result for Al-GSA Composites

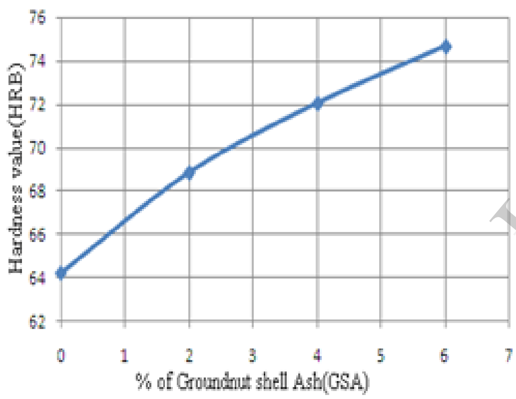

Fig 1: Hardness graph for Al-GSA composites

Specimen with 0% GSA result of hardness is less where as composites with 2%, 4%, and 6% of GSA. Finally the above plotted graph concludes that hardness of Al-GSA composites increases with increase of groundnut shell ash composition

% of GSA content	HRB
0	63.04
2	68.01
4	70.22
6	72.23

Table 5: Hardness result for heat treated AL-GSA Composites

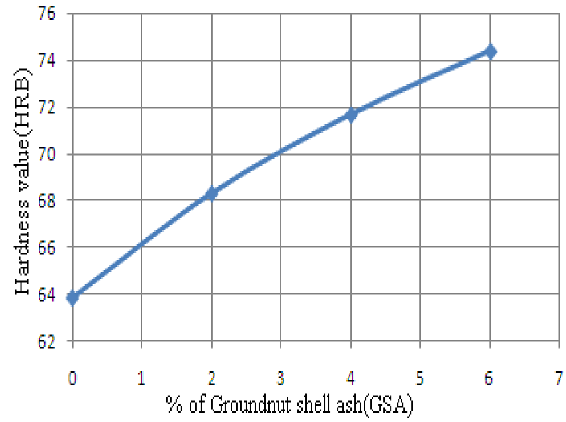

Fig 2: Hardness graph for heat treated Al-GSA composites

Above graph is plotted after the heat treatment of Al-GSA composites for soaking period of 1 hr at constant temperature of 180˚C. This graph almost coincides with the previous graph which was plotted before heat treatment. Finally the above plotted graph concludes that the normal temperature doesn't affect to hardness of Al-GSA composites.

Soaking period (in hours)	HRB Value
3	77.56
6	79.65
9	81.01
12	81.56
15	78.06
17	75.21

Table 6: Hardness result for heat treated hardest AL-GSA Composites

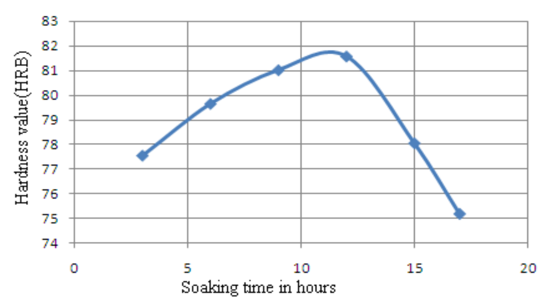

Fig 3 : Hardness graph for hardest Al-GSA composites

Above graph shows the variation of hardness with respect to soaking time for the composite which contains 6% of groundnut shell ash. It can be observed in the above graph that hardness of Al-GSA composite increases up to 12 hours of soaking time and starts going down after that. So it is concluded that these composites cannot hold good for a long period of heating.

% of GSA content	Density(g/cc)
0	2.65
2	2.35
4	2.08
6	1.98

Table 7: Result for density variation

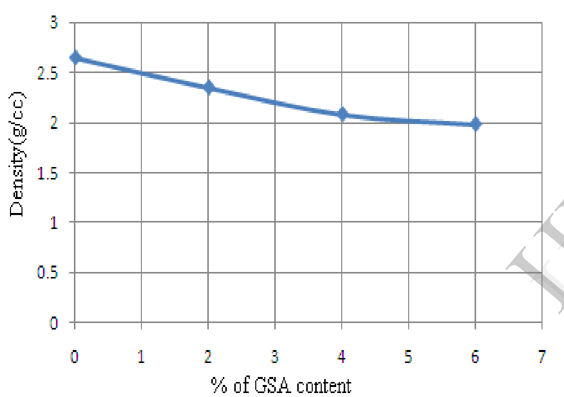

Fig 4: Reduced density graph for Al-GSA composites

The above graph shows the effect of Groundnut shell ash (GSA) on the density of Al-GSA composites. It can be observed from the plotted trend that the densities of Al-GSA composites are too low in comparison with pure aluminium. Finally GSA reduces the weight of composites for unit volume.

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