

Investigation of Mechanical Properties on Aluminium Based Hybrid Composites

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ABSTRACT: Metal Matrix Composites (MMCs) are highly attractive for large range of hi-tech engineering applications because of their useful Mechanical properties like hardness, toughness, compressive strength & tensile strength. Conventional monolithic materials have limitations with respect to composite material. Development of hybrid metal matrix composites has become an important area of research interest in Material Science. Aluminum alloys are widely used in aerospace and automobile industries due to their low density and good mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys. The aim of the present investigation is provide the detailed review on effect of hybrid reinforcement like coconut shell ash on mechanical behavior of aluminum matrix composite.

The present work aims to utilize agricultural waste in the production of metal matrix composites(MMCs) using the most widely used stir casting process which could be used for the manufacture of various components in automobile and aircraft industries with reduced weight and increased strength. Coconut shell ash is a fibrous waste obtained from the mesocarp of coconut and if not disposed properly can lead to serious environmental problem. The idea is to use this waste in the fabrication of low-cost composite materials. The paper deals with the fabrication of aluminum based hybrid metal matrix composite and then characterized their mechanical properties such as hardness and tensile strength. A recently developed modification of stir casting has been used in the present investigation to produce aluminum (6061) alloy reinforced with boron carbide (B_4C). Here Aluminum (6061) alloy is used as a base metal and boron carbide (B_4C) is a reinforced material with the hybrid reinforcement as coconut shell ash. The overview indicates that the developed method is quite successful and there is an increase in the value of tensile strength and hardness with increase in weight percentage of reinforcement.

KEYWORDS: Aluminum alloy (6061), reinforcement-boron carbide, Hybrid composite-coconut shell ash, Stir casting method, hardness test, tensile test.

I.INTRODUCTION

Composite materials are a mixture or a combination of two or more constituents differing in form and material composition and that are essentially insoluble in each other. Both constituents maintain their identity as they do not dissolve or melt in each other, and act in such a way that a new material results whose properties are better than the sum of their constituents. The incorporation of several different types of ceramic particulates into a single matrix has led to the development of hybrid composites. Also, using a hybrid composite that contains two or more types of particulates, the advantages of one type of particulates could complement to what is lacking in the other. [1]. Nowadays, the use of agro- wastes as a secondary reinforcement in the fabrication of composites is gaining more importance. The advantages of using these wastes are production of low cost by-products reduction in the cost of aluminum products [2], readily available with less cost, and often lower densities in comparison with most technical ceramics (boron carbide and alumina). Many researchers have reported the potentials and limitations of the use of wastes as reinforcements. [3, 4].

Aluminum matrix composites (AMCs) are noted for their unique combination of mechanical, physical and chemical properties which are scarcely attainable with the use of mono-ithic materials [5, 6]. This has made AMCs a strong

competitor to steel in terms of versatility for use in a wide range of engineering applications [7]. AMCs are currently applied in the design of components for automobiles, aircrafts, marine structures and facilities, defence assemblies, sports and recreation among many others [8, 9]. Agro waste ashes obtained by the controlled burning of agro waste products such as bamboo leaf, coconut shell, ground nutshell and rice husk among others have the advantages of low densities and processing cost compared with common synthetic reinforcing ceramics such as silicon carbide and alumina [14, 15]. The agro waste ashes have been successfully utilized to produce Al matrix composites with property levels which can be improved with the complement of synthetic reinforcements such as silicon carbide and alumina [16].

The present research is focused to utilize the coconut ash shell by dispersing it into the aluminium alloy (6061) and reinforced metal boron carbide (B_4C) to produce matrix composites through stir casting method. The various weight fractions of coconut ash shell particles and boron carbide are considered in the study. Experiments have been conducted to assess the mechanical behaviour (HARDNESS AND TENSILE TEST) of the Aluminum Metal Matrix composites. Further microscopic studies were conducted to establish the wear mechanisms and transition from one mechanism to another using the scanning electron microscope (SEM).

II. MATERIAL SELECTION

1. ALUMINIUM 6061
2. BORON CARBIDE (B_4C)
3. COCONUT SHELL ASH

ALUMINIUM 6061: Aluminium 6061 is a precipitation-hardened aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S", it was developed in 1935. It has good mechanical properties and exhibits good weld ability. It is one of the most common alloys of aluminium for general-purpose use. The mechanical properties of 6061 depend greatly on the temper, or heat treatment, of the material. Young's Modulus is 69 GPa (10,000 ksi) regardless of temper.



FIG.1. ALUMINIUM 6061

TABLE.1. CHEMICAL COMPOSITION OF AL 6061

Element	Mg	Si	Mn	Cu	Fe	Ti	Cr	Zn	Al
Weight %	1.08	0.63	0.52	0.32	0.17	0.02	0.014	0.031	Remainder

BORON CARBIDE

Boron Carbide is one of the hardest materials known, ranking third behind diamond and cubic boron nitride. It is the hardest material produced in tonnage quantities. Originally discovered in mid 19th century as a by-product in the production of metal borides, boron carbide was only studied in detail since 1930. Boron carbide powder is mainly produced by reacting carbon with B_2O_3 in an electric arc furnace, through carbo thermal reduction or by gas phase reactions. For commercial use B_4C powders usually need to be milled and purified to remove metallic impurities.



FIG.2. BORON CARBIDE

TABLE.2.CHEMICAL COMPOSITION OF BORON CARBIDE

Element	Total boron	Total carbon	Total iron	Total B+C	Other
Weight %	77.5	21.5	0.2	99	0.8

COCONUT SHELL ASH

Coconut shell is an agricultural waste and is available in very large quantities throughout the tropical countries of the world. Moreover, coconut is becoming an important agricultural product for tropical countries around the world as a new source of energy-biofuel. Previously, coconut shell was burnt as a means of solid waste disposal which contributed significantly to CO₂ and methane emissions. However as the cost of fuel oil, natural gas and electricity supply has increased and become erratic, coconut shell has come to be regarded as source of fuel rather than refuse. Presently, the Nigeria coconut shell is used as a source of fuel for the boilers, and residual coconut shell is disposed off as gravel for plantation roads maintenance. Black smiths also buy the coconut shell as fuel material in their casting and forging operations.



FIG.3. COCONUT SHELL ASH

TABLE.3.CHEMICAL COMPOSITION OF COCONUT SHELL ASH

Element	Al ₂ O ₃	CaO	Fe ₂ O ₃	K ₂ O	MgO	Na ₂ O	SiO ₂	MnO	ZnO
Weight %	15.6	0.57	12.4	0.52	16.2	0.45	45.05	0.22	0.3

III.EXPERIMENTAL SETUP

1. STIR CASTING PROCESS

The Stir casting method (also called liquid state method) is used for the hybrid composite materials fabrication, in which a dispersed phase is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technologies. Stir casting process is used to fabricate composite consists of an induction furnace with three mild steel stirrer blades. Here, the reinforcements are distributed into molten aluminium matrix by mechanical stirring. During preheating stage, the reinforcements are heated separately nearer to main process temperature of 400°C while aluminium is melted in a separate crucible at a temperature of 830°C. Now, the preheated reinforcements are mechanically

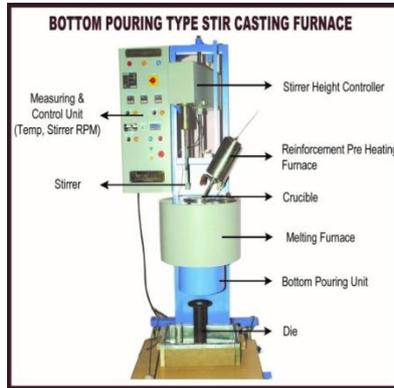


TABLE.4.PROCESS PARAMETERS

Stirrer Speed	500 – 600 RPM
Stirrer Time	3.5 Mins
Preheat Temperature	400°c
Stirrer Temperature	750°c

TABLE.5.COMPOSITIONS OF COMPOSITES

Specimen .No.	Al 6061 In Wt%	B4CIn Wt%	Coconut Shell Ash In Wt%
1	94	5	1
2	100	-	-
3	90	8	2
4	95	3	2

TESTING

The **Rockwell hardness test method**, as defined in ASTM E-18, is the most commonly used hardness test method. You should obtain a copy of this standard, read and understand the standard completely before attempting a Rockwell test. The Rockwell test is generally easier to perform, and more accurate than other types of hardness testing methods. The Rockwell test method is used on all metals, except in condition where the test metal structure or surface conditions would introduce too much variations; where the indentations would be too large for the application; or where the sample size or sample shape prohibits its use.



TENSILE TEST

The engineering Tensile Test is also known as tension test which vary widely used for providing the base of the design information on the strength of material and as an acceptance test for the specification of the materials. Tensile Tests are very simple, relatively, inexpensive, and fully standardized. Under the pulling type of loading something, it can be very quickly determined how the material will react to these types of forces being applied in tension. As the materials are being pulled, its strength and elongation can be found out. A lot of about a substance can be learned from tensile testing. As the machine continues to pull on the material until it breaks, a good, complete tensile profile is obtained. The curve shows how it reacted to the forces being applied. In the tension test a specimen is subjected to a continually increasing one directional tensile force while simultaneous observations are made of the elongation of the ductile specimen.

The tensile testing was done using a computerized UTM testing machine as per the ASTM E-8 standards. The sample rate was 9.103 pts/sec and crosshead speed 5.0 mm/min. Standard specimens with 36 mm gauge length were used to evaluate ultimate tensile strength, yield strength and percent elongation.



TABLE.6.PROCESS PARAMETERS

Total length	18.5 cm
Distance between shoulders	9 cm
Gauge length	7.5 cm

MICROSTRUCTURE

The composites produced were examined by inverted metallurgical microscope to analyze the microstructure. A section was cut from the castings diameter of 30mm and height 15mm, which is first, belt grinded followed by polishing with different grade of abrasive sheets papers. After that they were washed and again cloth polishing of alumina powder to remove the oxidant content was done. After cleaning process the sample was etched with the help of etchant (mixture of acid). After etching they were examined for microstructure under inverted metallurgical microscope which will work under reflection principle.



IV.RESULT

HARDNESS AND TENSILE BEHAVIOUR:-

The graph of the hardness and tensile strength of the aluminium composite according to mixture of B₄C, Coconut Shell Ash are shown in the below. From the observation we can see that hardness and tensile strength of the aluminium based composites are decreased when compared to pure aluminium because of blow holes produced in the composites, lack of wettability and improper bonding between the reinforcement materials.

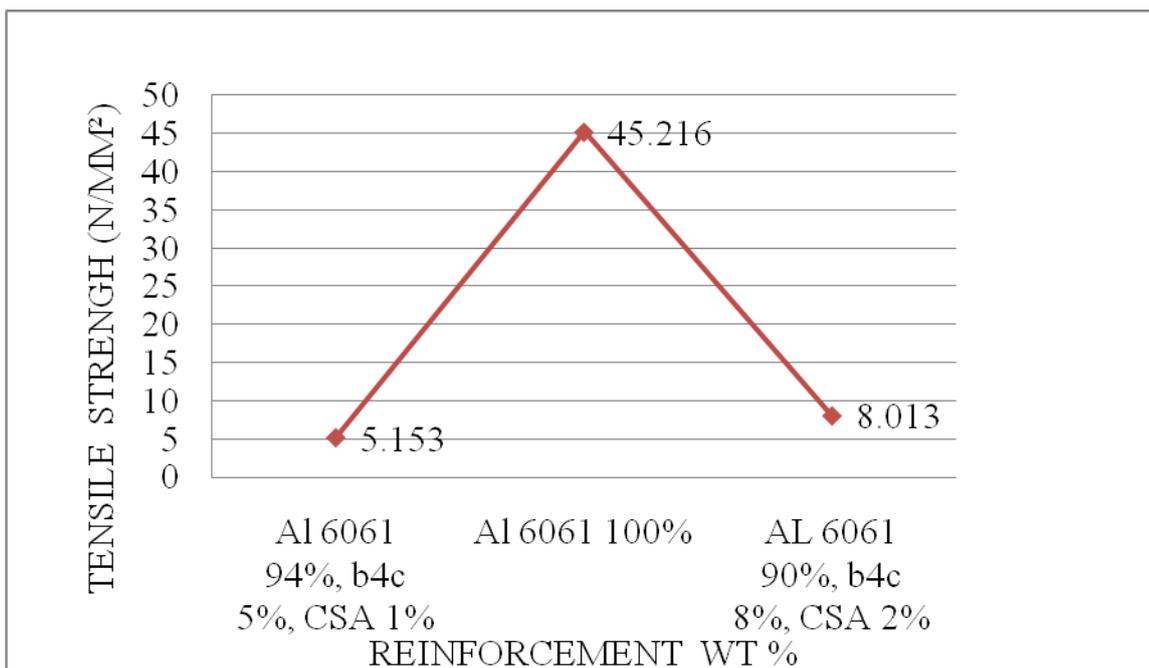
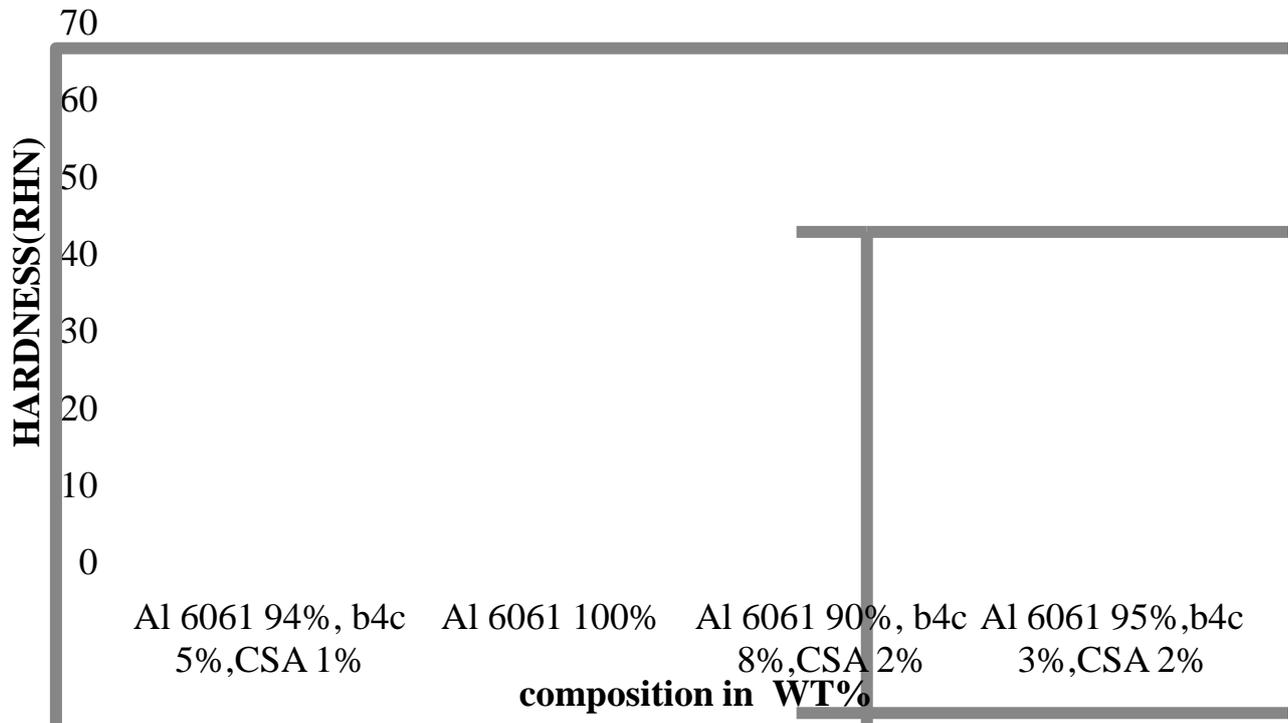
It is observed that the maximum hardness is observed at Al6061 (100%) which might leads to the deformation when subjected to strain. Incorporation of coconut shell ash particles with this significantly improves the hardness and also the deformation of the Al matrix. It is observed that the fact that the combination of B₄C with coconut shell ash particles possess lower hardness than the aluminium. Thus, it can be concluded that the mechanical properties such as density, tensile strength, yield strength and hardness of the composites decreases by increasing B₄C, coconut shell ash and their mixtures. Because of the problems found that the increase of porosity and lack of wettability of B₄C and CSA the blowholes are produced in the composite materials while casting.

TABLE.7.HARDNESS TEST VALUES

S.N o.	Specimen	RHN
1	Al 6061 94%, B ₄ C 5%, CSA 1%	61
2	Al 6061 100%	62
3	Al 6061 90%, B ₄ C 8%, CSA 2%	56
4	Al 6061 95%, B ₄ C 3%, CSA 2%	46

TABLE.8.TENSILE TEST VALUES

S. No	Specimen	Tensile strength N/Mm ²
1	Al 6061 94%, B ₄ C 5%, CSA 1%	5.153
2	Al 6061 100%	45.216
3	Al 6061 90%, B ₄ C 8%, CSA 2%	8.013



MICROSTRUCTURE

As the microstructure plays an important role in the overall performance of a composite and the physical properties depend on the microstructure, reinforcement particle size, shape and distribution in the alloy, prepared samples were examined using an inverted metallurgical microscope to observe the internal structure of composites. The micrographs shown in below and 16 depict the microstructure of as cast pure Al 6061 and B₄C and CSA reinforced Al 6061.

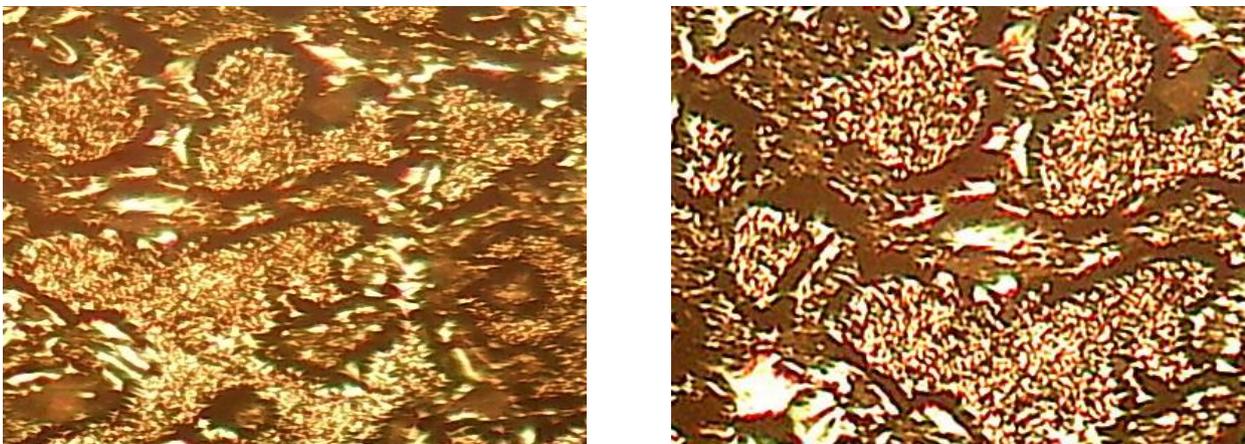


FIG.4. Microstructure of the specimen

V. CONCLUSION

Aluminium based MMC reinforced with B₄C particles and hybrid composite like coconut shell ash were fabricated using the stir casting process and the hardness, tensile test and micro structure of the fabricated MMC according to the working conditions were also evaluated.

The mechanical behaviour of Aluminium metal matrix hybrid composite containing different percentage of B₄C & coconut shell ash as reinforcement has been investigated. The result shows-

- The hardness of the hybrid composite decreased slightly with the comparison of Aluminium 6061 as shown in graph.
- Tensile strength reduction of the hybrid composite was obtained with the comparison of Aluminium 6061 as shown
- The fracture toughness of the hybrid composition was observed to be superior to that of the single reinforced Aluminium 6061.
- In future work, further addition of K₂TiF₆ to the reinforcement will increase the wettability and reduces the porosity of the composite material. So the hardness and tensile strength of the composite will be improved.

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