

EXPERIMENTAL ANALYSIS OF METAL MATRIX COMPOSITE REINFORCED WITH SUGARCANE BAGASSE ASH

*Aderemi DADA*¹ and *Wahab AJIBOLA*²
^{1,2}Department of Mechanical Engineering
The Federal Polytechnic, Ilaro
Ogun State, Nigeria.

Abstract - The desire to provide a material of high quality and low weight has made metal matrix composite (MMC) undergo important consideration in recent years. Composite materials obtained by adding particles to the metals matrix have made remarkable progress in its development and application in aerospace and automotive industries. In this study, the micro structural and mechanical properties of zinc aluminum alumina reinforced with sugarcane bagasse ash were examined. Sugarcane bagasse ash is an agro waste generated from sugarcane. Solid sugarcane bagasse were poured and burnt on a steel plate in an open air for three hours. The ash obtained was condition in the furnace at temperature of 110°C for 180mins. Six samples were prepared with different composition. Alumina, and sugarcane bagasse were used as reinforced phase with zinc aluminum alloy at 100% Al and 0, 1,1.5,2,2.5wt.% bagasse ash. The agro wastes and alumina were preheated before being introduced into the zinc aluminum composite in molten state. The mechanical properties such as tensile strength, hardness test and torsion were used to characterize the composite produced. The result shows an increase in hardness, tensile and shear strength in sample C (1.0wt%SCBA,0.5wt%Al₂O₃) but gradually reduced in sample D(1.5wt%SCBA,0.5wt%Al₂O₃, sample E (2.0wt%SCBA,0.5wt%Al₂O₃) and sample F (2.5wt%SCBA,0.5wt%Al₂O₃) a linear relationship was established between increase in sugarcane bagasse (SCBA) and decrease in hardness, tensile and torsion. Sample C(1.0wt%SCBA,0.5wt%Al₂O₃) has the maximum value in hardness, tensile and torsion.

Keywords: Bagasse,, Composite, Matrix, Reinforcement, Sugarcane, Hardness, Wear.

I. Introduction

Sugarcane bagasse is a waste produced after sugarcane juice has been extracted from sugarcane in the mills and it can be used for power generation. The ash produced in the process is known as bagasse ash that can be combined with other substances to form material with superior engineering material with improved mechanical properties. The use of alloy elements such as manganese, tungsten, nickel, chromium and vanadium to improve specific mechanical and micro-structural properties in some engineering materials through heat treatment usually culminate in costly materials, whereas cost and durability are the major considerations in engineering material selection. Therefore, this study examined micro-structural and mechanical properties of zinc aluminum reinforced with alumina and sugarcane bagasse ash with the intention of producing high quality and relatively cheap engineering material. The study will further facilitate the understanding of metal matrix composite reinforced with sugarcane bagasse and reveal an improved and effective means of disposing environmental waste such as sugarcane bagasse.

The advancement in material science has increased the application of metals with specific property for use in engineering components. The introduction of ceramics reinforcement to metal matrix composite can improve strength, hardness, wear, and corrosion resistance [1]. Reinforcement materials for aluminum matrix composite such as rice husk ash, palm oil shell ash and ceramic material have been used with carbides, nitride and alumina to produce durable and economical engineering materials with high quality mechanical properties that has been used as bearing materials with excellent corrosion and wear resistance.

The word “composite” is widely used for material which consists of a distinct constituent (the reinforcement) disperse in an uncontrollable phase (the matrix), and which derives its unique characteristics from the properties of its components, the geometry and structure of the component, and the properties of the boundaries (interfaces). Precise effect of uniform dispersion of reinforcement in the matrix has been achieved with two step mixing method of stir casting technique and conducting experiment with various weight fraction of Al_2O_3 .to achieve better homogeneity.[2]

Sugarcane bagasse (SCB) is a huge by-product of sugarcane obtained after the extraction of juice and it contains considerable amount of ashes. The ashes which constitute about 8-10% contain high amounts of un-burnt matter like silicon, aluminum, iron and calcium oxides. The ashes, obtained directly from the mill, are not reactive because they are burnt under uncontrolled condition at very high temperatures.

Zinc- aluminum matrix is a very good bearing material because of its low weight, excellent fluidity and wear resistance [3] Zinc- aluminum composite is a superb material that is becoming increasingly popular in many engineering applications, especially in automobiles and aerospace industries. It is glaring from recent development that metal matrix composite may replace traditional materials in many commercial and industrial applications in the near future. Aluminum and its alloys have been used, as a matrix for variety of reinforcement; as a result advanced metal matrix composites with improved properties have been obtained. The combination of light weight, corrosion resistance and favorable mechanical properties has made aluminum alloy very popular for use as metal composite.

Aluminum based alloy matrix has been successfully utilized in the development of high performance components in defense, marine and other industrial applications because of the broad range of excellent physical and mechanical properties, and good finishing characteristic. [2]. In metal matrix composite the continuous or matrix phase is a monolithic alloy and the reinforcement consist of materials with high strength, good density, good thermal resistance, which in reality can be in form of fibers or particulate. Fibers and particles are used in MMCs to increase strength and thermal conductivity, reduce weight, friction and wear under heavy load The use of particulate reinforcements such as silicon carbide (SiC), which is not produced in most developing countries has a disadvantage of extra cost and high weight.

Furthermore, the fabrication of discontinuous Zn-Al based MMCs can be achieved by standard metal processing technologies such as powder metallurgy, direct casting, rolling, forging, and extrusion and the products can be machined using conventional manufacturing processes. The addition of graphite particles to Zn-Al alloy improves wear behavior in metal matrix composites; hence zinc-aluminum alloys have found wide industrial application. The members of ZA alloys are ZA-8, ZA-12 and ZA-27 alloys. These alloys have effectively competed with copper, aluminum and other foundry based alloy in engineering application [4]. However, at elevated temperature, the mechanical and physical properties of zinc aluminum alloys are unsatisfactory. Modern engineering applications require materials that have great energy to weight ratio that can be used where high performance is required. The combination of

metallic properties of matrix alloys (ductility and toughness) with ceramic reinforcement (high strength and high modulus) offers greater strength that distinguishes it as the most commonly used metallic alloy for metal matrix material[1].

II. Methodology

A The Sugarcane Bagasse and Metal Matrix Composite

Sugarcane bagasse is a waste product generated in agricultural industry and it is readily available in Nigeria. After the consumption of sugarcane people simply discard the bagasse as waste due to its little economic value. It is a fibrous residue of cane stalks produced after crushing and extraction of juice from the sugarcane. Bagasse is usually grey-yellow to pale green color. It is cumbersome and quite irregular in particle size. The sugarcane residue is a poorly utilized, renewable agricultural material that encompasses two unique cellular compositions. The first is a thick walled, lengthy, fibrous fraction derived from the skin and fibrous-vascular bundles dispersed all through the internal portion of the stalk. The second is a pith fraction derived from the thin walled cell from the ground tissue. The primary chemical compositions of bagasse are cellulose, hemicellulose and lignin. Hemicellulose and cellulose are present in the form of hollow cellulose in bagasse which contributes approximately 70% of the overall chemical constituents found in bagasse is lignin which serves as an energy conservation system [5].

B Preparation and Production of the Agro-Waste Material

Pure zinc ingot and aluminum 6011 alloy were used in the production of zinc-aluminum (Zn-Al) alloy matrix. Chemically pure aluminates particles (Al_2O_3) having average particle size (5micron) and agro waste material which is the sugar cane bagasse ash (SCBA) derived from controlled burning and sieving of dry sugarcane were employed. The sugarcane bagasse ash was used as reinforcement for the Zn-Al based composite. Tests sample with varying composition of this reinforcement were produced.. The agro waste, sugarcane bagasse (SCB) was burnt in an open air (uncontrolled combustion) for three hours to produce sugarcane the bagasse ash (SCBA).

The chemical composition of the aluminum used is presented in the tables below.

Table2.1.Elemental composition of aluminum

ELEMENTS	WEIGHT PERCENTAGE %
Fe	0.745
Si	0.483
Mn	0.122
Cu	0.122
Zn	0.272
Ti	0.010
Mg	0.347
Pb	0.180
Sn	0.003
Al	97.88

The agro waste materials (sugarcane bagasse) were obtained from a nearby local market at Papalanto in Ogun State in Nigeria. The already dried solid bagasse were poured on a steel plate outside an

open air and set on fire with the use of a match stick and gas fuel. It burned vigorously for two hours after which it was allowed to burn in open air for about three hours. The volume reduced drastically during burning, the remains were gathered into a crucible and left to continue burning for a whole day. The ash obtained in the drum was allowed to cool in the steel plate before removal. The ash obtained was then conditioned in a furnace at temperature of 110⁰C for 180 minutes to reduce the volatile constituents of the ash.

C Preparation of the Mould

Cylindrical wooden patterns (single piece) were selected with molding box, the mould was then prepared. This started with collapsing of the previously made mould with the use of a shovel and hammer, the molding sand was conditioned with water and mixed, and the sieving of the facing sand inside the head pan was effected. The drag was prepared, facing coming first, followed by ramming. Parting line was created along the side of the patterns to facilitate allowance for easy removal and parting sand was applied on the face of the drag.. The cope was then prepared creating cavity in it with spruce pins.

D Production of the Metal Matrix Composite

Two step stir casting process was used for production of the composite material; this was adopted to allow homogeneity and even distribution of particles. The Al₂O₃ particles were pre-heated to a temperature of about 250⁰C for 2 hours and then sieved to obtain fine ash grain size (about 150µm) and to remove impurities. The aluminum was fired in the furnace and heated to a temperature of about 670⁰C till it melts completely. Zinc was then charged into the furnace and allowed to melt completely. The melt was returned to the furnace after stirring and heated for 7 minutes. The pre-heated Al₂O₃ particles were charge into the furnace, followed by the sugarcane bagasse ash particles. A gas fired crucible furnace was used for the operation. The slurry was cast into the moulds and the process was repeated for the rest of the samples.

Table 2.2: Composition of the SCBA.

SAMPLE	ZINC %	ALUMINIUM %	AL ₂ O ₃ %	SCBA%
A	0	100	0	0
B	73	27	0	0
C	71.5	27	0.5	1.0
D	71	27	0.5	1.5
E	70.5	27	0.5	2.0
F	70	27	0.5	2.5

Table 2.3: Charge Calculation

SAMPLE	ZINC(g)	ALUMINIUM(g)	AL ₂ O ₃ (g)	SCBA(g)
A	0	848.34	0	0
B	1356.01	501.54	0	0
C	1312.88	495.774	9.181	18.362
D	1297.98	493.60	9.14	27.422
E	1300.18	494.44	9.156	36.625
F	1268.61	489.321	9.06	45.3075

III. Experimental Analysis and Test

A Experimental Analysis

*Density of Aluminium = 2.7g/cm³ Density of Zinc = 7.1g/cm³ of sugarcane Ash
 = 1.98g/cm³ Density of Aluminate = 3.75g/cm³*

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

The volume of specimen (cylindrical in shape)

$$V = \pi r^2 l \text{ (Volume of a cylinder)}$$

$$D= 2.0\text{cm}, L= 20\text{cm}$$

$$V = \pi \times 1.0^2 \times 20$$

$$V = 62.84\text{cm}^3$$

Sample A

$$\delta Al \times w\%Al$$

$$2.7 \times 100\%Al$$

$$2.7 \times 2.7$$

$$\text{Mass/volume} = 2.7\text{g/cm}^3$$

$$\text{Mass} = 62.84 \times 2.7$$

$$\text{Mass} = 169.668\text{g}$$

Mass ratio/percentage

Aluminium(Al)

$$\text{Mass (AL)} = 1 \times 169.668$$

$$\text{Mass (AL)} = 169.668\text{g}$$

For two patterns

$$\text{Mass (AL)} = 169.668 \times 5$$

$$\text{Mass (AL)} = 848.34\text{g}$$

Sample B

$$\delta\text{Al} \times w\% \text{Al} + \delta\text{Zn} \times w\% \text{Zn}$$

$$2.7 \times 27\% \text{Al} + 7.1 \times 73\% \text{Zn}$$

$$2.7 \times 0.27 + 7.1 \times 0.73$$

$$0.729 + 5.183$$

$$\text{Mass/volume} = 5.912\text{g/cm}^3$$

$$\text{Mass} = 62.84 \times 5.912$$

$$\text{Mass} = 371.51\text{g}$$

Mass ratio/percentage

Aluminium(Al)

$$\text{Mass (AL)} = 0.27 \times 371.51$$

$$\text{Mass (AL)} = 100.307\text{g}$$

For two patterns

$$\text{Mass (AL)} = 100.307 \times 5$$

$$\text{Mass (AL)} = 501.54g$$

Zinc (Zn)

$$\text{Mass (Zn)} = 0.73 \times 371.51$$

$$\text{Mass (Zn)} = 271.20g$$

For two patterns

$$\text{Mass (Zn)} = 271.20 \times 5$$

$$\text{Mass (Zn)} = 1356.01g$$

Sample C

(0.5% Al₂O₃, 1.0% SCBA)

$$\delta Al \times w\%Al + \delta Zn \times w\%Zn + \delta Al_2O_3 \times w\%Al_2O_3 + \delta SCBA \times w\%SCBA$$

$$2.7 \times 0.27 + 7.1 \times 0.715 + 3.75 \times 0.005 + 1.98 \times 0.01$$

$$0.729 + 5.0765 + 0.01875 + 0.0198$$

$$5.844g/cm^3$$

$$\text{Mass/volume} = 5.844g/cm^3$$

$$\text{Mass} = 62.84 \times 5.844$$

$$\text{Mass} = 367.24g$$

Mass ratio/percentage

Aluminium(Al)

$$\text{Mass (AL)} = 0.27 \times 367.24$$

$$\text{Mass (AL)} = 99.15g$$

For two patterns

$$\text{Mass (AL)} = 99.15 \times 5$$

$$\text{Mass (AL)} = 495.774g$$

Zinc (Zn)

$$\text{Mass (Zn)} = 0.715 \times 367.24$$

$$\text{Mass (Zn)} = 262.58$$

For two patterns

$$\text{Mass (Zn)} = 262.58 \times 5$$

$$\text{Mass (Zn)} = 1312.88g$$

Aluminate (Al₂O₃)

$$\text{Mass (Al}_2\text{O}_3) = 0.005 \times 367.24$$

$$\text{Mass (Al}_2\text{O}_3) = 1.836g$$

For two patterns

$$\text{Mass (Al}_2\text{O}_3) = 1.836 \times 5$$

$$\text{Mass(Al}_2\text{O}_3) = 9.181g$$

Sugarcane bagasse ash (SCBA)

$$\text{Mass (SCBA)} = 0.01 \times 367.24$$

$$\text{Mass(SCBA)} = 3.6724g$$

For two patterns

$$\text{Mass (SCBA)} = 3.6724 \times 5$$

$$\text{Mass (SCBA)} = 18.362g$$

Sample D

(8% Al₂O₃ 2%SCBA)

$$\delta Al \times w\%Al + \delta Zn \times w\%Zn + \delta Al_2O_3 \times w\%Al_2O_3 + \delta SCBA \times w\%SCBA$$

$$2.7 \times 0.27 + 7.1 \times 0.71 + 3.75 \times 0.005 + 1.98 \times 0.015$$

$$0.729 + 5.041 + 0.01875 + 0.0297$$

$$\text{Mass/volume} = 5.8185\text{g/cm}^3$$

$$\text{Mass} = 62.84 \times 5.8185$$

$$\text{Mass} = 365.63\text{g}$$

Mass ratio/percentage

Aluminium(Al)

$$\text{Mass (AL)} = 0.27 \times 365.63$$

$$\text{Mass (AL)} = 98.72\text{g}$$

For two patterns

$$\text{Mass (AL)} = 98.72 \times 5$$

$$\text{Mass (AL)} = 493.60\text{g}$$

Zinc (Zn)

$$\text{Mass (Zn)} = 0.71 \times 365.63$$

$$\text{Mass (Zn)} = 259.59\text{g}$$

For four patterns

$$\text{Mass (Zn)} = 259.59 \times 5$$

$$\text{Mass (Zn)} = 1297.98\text{g}$$

Aluminate

$$\text{Mass(Al}_2\text{O}_3) = 0.005 \times 365.63$$

$$\text{Mass (Al}_2\text{O}_3) = 1.828\text{g}$$

For two patterns

$$\text{Mass (Al}_2\text{O}_3) = 1.828 \times 5$$

$$\text{Mass (Al}_2\text{O}_3) = 9.14\text{g}$$

Sugarcane bagasse Ash

$$\text{Mass (SCBA)} = 0.015 \times 365.63$$

$$\text{Mass (SCBA)} = 5.485g$$

For two patterns

$$\text{Mass (SCBA)} = 5.485 \times 5$$

$$\text{Mass (SCBA)} = 27.422g$$

Sample E

(0.5% Al_2O_3 , 2.0% SCBA)

$$\delta Al \times w\%Al + \delta Zn \times w\%Zn + \delta Al_2O_3 \times w\%Al_2O_3 + \delta SCBA \times w\%SCBA$$

$$2.7 \times 0.27 + 7.1 \times 0.71 + 3.75 \times 0.005 + 1.98 \times 0.02$$

$$0.729 + 5.041 + 0.01875 + 0.0396$$

$$5.828g/cm^3$$

$$\text{Mass/volume} = 5.828g/cm^3$$

$$\text{Mass} = 5.828 \times 62.84$$

$$\text{Mass} = 366.25g$$

Mass ratio/percentage

Aluminum (Al)

$$\text{Mass (AL)} = 0.27 \times 366.25$$

$$\text{Mass (AL)} = 98.88g$$

For two patterns

$$\text{Mass (AL)} = 98.88 \times 5$$

$$\text{Mass (AL)} = 494.44g$$

Zinc (Zn)

$$\text{Mass (Zn)} = 0.71 \times 366.25$$

$$\text{Mass (Zn)} = 260.04g$$

For two patterns

$$\text{Mass (Zn)} = 260.04 \times 5$$

$$\text{Mass (Zn)} = 1300.18g$$

Aluminate(Al_2O_3)

$$\text{Mass (Al}_2\text{O}_3) = 0.005 \times 366.25$$

$$\text{Mass (Al}_2\text{O}_3) = 1.83g$$

For two patterns

$$\text{Mass (Al}_2\text{O}_3) = 1.83 \times 5$$

$$\text{Mass (Al}_2\text{O}_3) = 9.156g$$

Sugarcane Bagasse Ash

$$\text{Mass (SCBA)} = 0.02 \times 366.25$$

$$\text{Mass (SCBA)} = 7.325g$$

For two patterns

$$\text{Mass (SCBA)} = 7.325 \times 5$$

$$\text{Mass (SCBA)} = 36.625g$$

Sample F

(0.5% Al_2O_3 , 2.5% SCBA)

$$\delta Al \times w\%Al + \delta Zn \times w\%Zn + \delta Al_2O_3 \times w\%Al_2O_3 + \delta SCBA \times w\%SCBA$$

$$2.7 \times 0.27 + 7.1 \times 0.70 + 3.75 \times 0.005 + 1.98 \times 0.025$$

$$0.729 + 4.97 + 0.1875 + 0.0498$$

$$5.767g/cm^3$$

$$\text{Mass/volume} = 5.767\text{g/cm}^3$$

$$\text{Mass} = 62.84 \times 5.767$$

$$\text{Mass} = 362.46\text{g}$$

Mass ratio/percentage

Aluminium(Al)

$$\text{Mass (AL)} = 0.27 \times 362.46$$

$$\text{Mass (AL)} = 97.86\text{g}$$

For two patterns

$$\text{Mass (AL)} = 97.86 \times 5$$

$$\text{Mass (AL)} = 489.321\text{g}$$

Zinc (Zn)

$$\text{Mass (Zn)} = 0.70 \times 362.46$$

$$\text{Mass (Zn)} = 253.722\text{g}$$

For two pattern

$$\text{Mass (Zn)} = 253.722 \times 5$$

$$\text{Mass (Zn)} = 1268.61\text{g}$$

Aluminate (Al_2O_3)

$$\text{Mass (Al}_2\text{O}_3) = 0.005 \times 362.46$$

$$\text{Mass (Al}_2\text{O}_3) = 1.8123\text{g}$$

For two patterns

$$\text{Mass (Al}_2\text{O}_3) = 1.8123 \times 5$$

$$\text{Mass (Al}_2\text{O}_3) = 9.06\text{g}$$

Sugarcane bagasse Ash (SCBA)

$$\text{Mass (SCBA)} = 0.025 \times 362.46$$

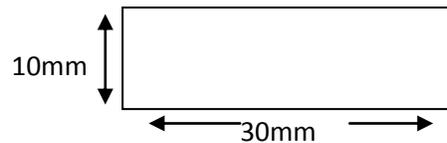


Fig. 3.1 Micro structural Specimen

$$\text{Mass (SCBA)} = 9.0015g$$

For two patterns

$$\text{Mass (SCBA)} = 9.0015 \times 5$$

$$\text{Mass (SCBA)} = 45.3075g$$

B Experimental Tests

This is the primary stage involved in metallographic examination processes. The processes include grinding, polishing, and etching before final examination under the metallurgical microscope. The specimen size is 10mm x 30mm x 20mm. The microstructure of the specimen is typical of sample E.

IV. Result and Discussion

The result of the hardness test is depicted in table 4.1. The Brinell hardness number (BHN) value reads maximum at sample C containing 0.5wt% Al₂O₃ 1.0wt% SCBA. It was observed that an increase in hardness was as a result of increase in Al₂O₃ particle and this is in conformity with the expected result. (Pruthviraj, 2011). However, the ductility of the composite material decreases with addition of SCBA at 1.5wt% SCBA 0.5wt% Al₂O₃ (sample D) the Zn-Al composite material showed rapid decline in hardness, and continue to decrease due to addition of SCBA. The reinforced composite materials exhibited better hardness values than the Zn-27 alloy material.



Figure 4.1:Microstructural Specimen (Sample A)



Figure 4.2:Microstructural Specimen (Sample B)

In figure 4.3, the micrograph of sample C shows a highly dispersed Al₂O₃ (alumina) and SCBA in the matrix which give rise to the hardness effect on sample C, unlike sample D which has 1.5wt%, therefore causes reduction in the hardness.



Figure 4.3:Microstructural Specimen (Sample C)



Figure 4.4:Microstructural Specimen (Sample D)

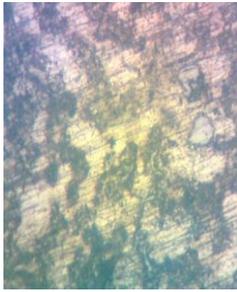


Figure 4.5: Microstructural Specimen (Sample E)



Figure 4.6: Microstructural Specimen (Sample F)

In figure 4.5 Sample E with 2.0wt % SCBA and 0.5wt% Al₂O₃ shows rapid decline in hardness because of increase in volume of SCBA presence in the matrix composite which is not uniformly dispersed which give rise to sharp reduction in hardness and shear stress. Sample F shows reduction in hardness due to heavy presence of SCBA (2.5%wt) with 0.5wt% Al₂O₃. The micrograph shows heavy presence of SCBA which is responsible for decline in hardness and tensile and shear strength.

Table 4.1 Hardness value of A-F composite samples.

SAMPLES	A	B	C	D	E	F
VALUE	19.9	21.6	59.8	54.2	50.9	38.5

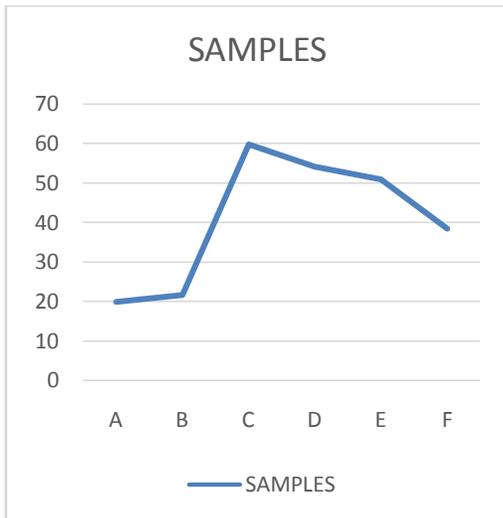


Fig 4.7 Graph of Hardness Values

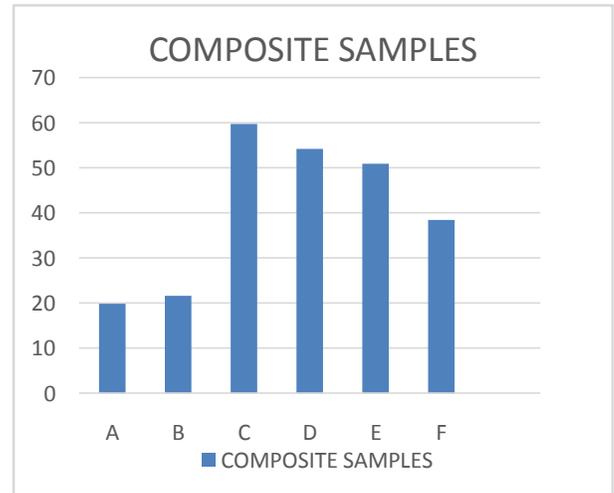


Fig. 4.8 Bar Chart of Hardness Values

Table 4.2: Tensile value of A-F composite samples.

SAMPLES	A	B	C	D	E	F
VALUE (Nmm ²)	67.6	73.4	203.2	184.2	172.9	130.8

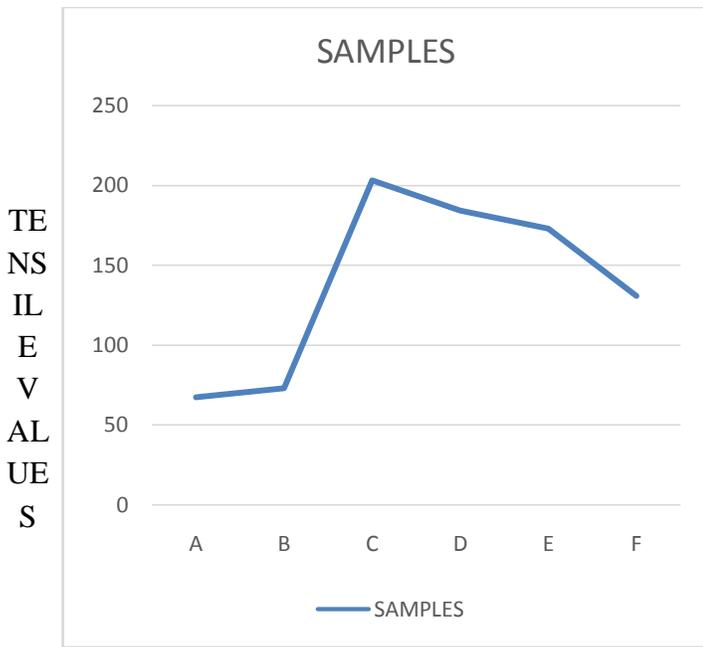


Fig 4.9 Graph of Tensile Values

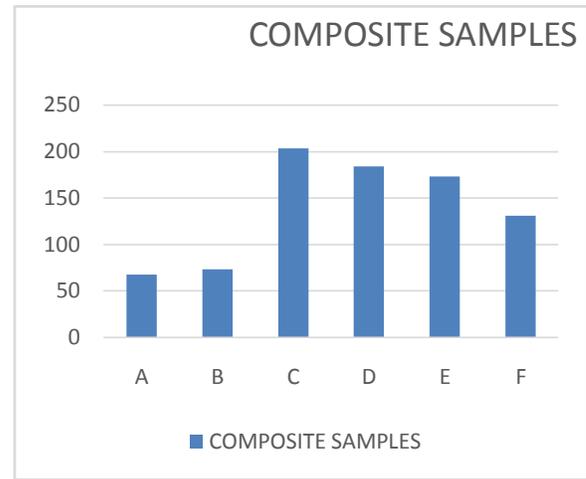


Fig.4.11 Bar Chart of Tensile Strength.

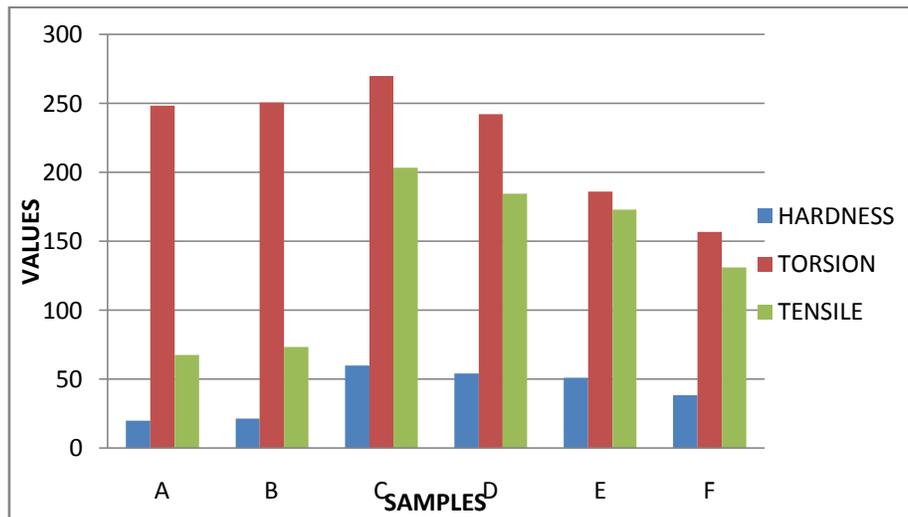


Fig.4.10. Comparative Bar Chart of Hardness, Tensile and Shear Strength

V. Conclusion

The mechanical properties of Zinc Aluminum alloy metal matrix composite containing Alumina and Sugarcane Bagasse ash (SCBA) containing 0, 1, 1.5, 2, 2.5wt% SCBA as reinforcement was investigated. The results shows that the hardness of the hybrid composites was observed to be superior compared to that of the Zn-27 alloy. The results of the hardness and tensile tests follow a linear pattern. SCBA particle has serious effect on the hardness of the composite material, The SCBA has a great

promise as a reinforcement material that can greatly reduce cost and produce high performance material with better mechanical properties.

References

- [1] **S.R.**, Teixeira, A.E. de Souza, G.T. Almerda Santos, A.F. Pena, A. G Miguel. Sugarcane Bagasse Ash as a Potential Quartz Replacement in Red Ceramic. *Journal of American Ceramic Society*. Vol.91. Issue 6 pp1883-1887. 2008
- [2] K.K., Alaneme, A. O.,Aluko, *Fracture Toughness and Tensile Properties of As-Cast and Age-Hardened Aluminium (6063) Silicon Carbide Particulate Composites*. *Scientia Iranica*. Vol.19. Issue 4. pp 992-996. Aug.2012.
- [3] S.Mitrovic, M. Babic, B. Stojanovic, N. Miloradovic. (2011). Tribological Potential of Hybrid Composites Based on Zinc and Aluminium Alloys Reinforced with SiC and Graphite Particles, 12th International Conference on Tribology,pp 138-145. 2011
- [4] S.A.,Olagoke. *Engineering Materials and Metal Forming*. First Edition. SAO Ventures, Ibadan, Nigeria Nigeria. (2006).
- [5] Tshawafo E. Motaung, Mokgaotsa J.Mochane. Systematic Review on Recent Studies on Sugarcane Bagasse and Bagasse Cellulose Polymer Composites. *Journal of Thermoplastic Composite Materials*. Vol.31 Issue 10. pp 1416-1432. 2017

Appendix



Sugarcane bagasse



Gas furnace

