Production and Characterization of Zinc-Aluminium, Silicon Carbide Reinforced with Palm Kernel Shell Ash

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Production and Characterization of Zinc-Aluminium, Silicon Carbide Reinforced with Palm Kernel Shell Ash

Ajibola W.A[1] ,Fakeye A .B [2]
Federal Polytechnic Ilaro, Department of Mechanical Engineering
Ilaro, Ogun- State Nigeria

ABSTRACT

The zeal to produce relatively high performance and materials which are light weighted and relatively low in cost has made metal matrix composite (MMCs) undergo major transition over the years. This research, production and characterization of Zinc-Aluminium composite reinforced with silicon carbide and palm kernel shell ash (PKSA). Samples were prepared with compositions 5wt% SiC added with 0.2%, 0.4%, 0.6%, 0.8% and 1.0wt% PKSA were utilized to prepare the reinforcing phase with Zinc-Aluminium matrix composite using two-step stir casting method. The agro-waste materials was preheated to 650^{0}c before being introduced into the Zinc-Aluminium composite in molten state. Hardness and tensile test were used to characterize the composite produced. The result shows that increase in PKSA reinforcement that gives increase in hardness and tensile strength, the microstructure shows that SiC and PKSA were well dispersed in the alloy matrix. In conclusion, the tensile and hardness characteristics improved with increase in PKSA reinforcement using 5% silicon carbide.

Keywords: *Casting, Composite, Composition, Microstructure and Reinforcement,*

Introduction

Metal matrix composite (MMCS) is a composite material with at least two constituents, with one being a metal and the other being a different material entirely such as ceramics or organic material. When at least three materials are present it is called an HYBRID. Metal matrix composite has potential advantages over monolithic alloys and this has activated considerable attention over the years. A monolithic materials cannot satisfy broad spectrum of properties required in modern engineering system [1].

Current application require material that are stronger light weight less expensive .Amaterials that have good strength to weight ratio suitable for automobile application where fuel economy with improve engine performance are becoming more critical [2].Metal matrix composite have range of properties which include high specific ratio, low coefficient of friction thermal expansion superior wear high specific stiffness and good corrosion resistance [3][4]..Metal matrix composition MMC application in aerospace automobile, defence and marine.

These composites have provided solution to the problem of increasing service requirements for various structural applications through the reinforcement of metal matrix by metallic or nonmetallic materials. Metal matrix composites are commonly reinforced with high strength and high modulus ceramics phases which may be in forms of fibres, whiskers or particulates. The addition of ceramics reinforcement to metal matrix improves strength, hardness, wear and corrosion resistance while ductility is reduced. Reinforcements commonly used in Aluminium matrix composites have been extended to include organic waste such as rice husk ash, coconut shell ash, palm oil shell ash and sugar cane bagasse while ceramic material being used as reinforcements include carbides, borides, nitrides and alumina. Commonly used metals as matrix in structural materials include Titanium, Aluminium and exotic metals such as Silver, Manganese, Berylium, Cobalt, Copper and Nickel. One of the mainly used composite is Aluminium Metal Matrix Composites (AMMC).

Aluminium(AL) is a silvery white and ductile member of the poor metal group of chemical elements. Aluminium matrix composite (AMCs) refers to the class of light weight high performance aluminium centric materials. Aluminium alloy has a specific gravity of 2.7g/cc thereby placing it among the light weighted structural metals. Six major elements constitute the aluminium alloy system and they consists of silicon, manganese, zinc, magnesium, copper and iron. Composites offers excellent thermal conductivity, high shear strength, excellent abrasion resistance, high thermal strength, non-flammability, minimal attacks by fuel and solvents and the ability to be formed and treated on conventional equipment. Reinforcements mainly used as Aluminium matrix composites have been extended to include organic wastes such as

rice husk ash, coconut shell ash, palm kernel shell ash, fly ash and sugar cane bagasse while ceramic reinforcements materials include carbides, borides, nitrides and alumina.[5]
Zinc-Aluminium alloys compared and varied with aluminium, copper, magnesium and other iron based alloys reported that at an increased temperature (100^0C) its properties are underwhelming and less satisfactory, its wear behavior is also of high concern. They are also important materials with light weight, high fluidability, good machinability, improved hardness and tensile strength, high wear resistance and castability[6].

Silicon carbide (SiC) is composed of the tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material. SiC is not attacked by any acid, alkalis or molten salts up to 800^0c. In air, silicon carbide forms a protective silicon oxide coating at 1200^0c and is able to be used up to 1600^0c. The high thermal conductivity coupled with low thermal expansion and high strength gives it exceptional thermal shock resistant qualities. Silicon carbide ceramics maintain their strength to very high temperatures even at 1600^0c with no strength loss. Properties of Silicon Carbide are low density, high strength, low thermal expansion, high thermal strength, hardness and high elastic modulus.[7].

Palm kernel Shell Ash (PKSA) comes from palm trees. Palm tree is a sub-tropical evergreen plant Elasis guineesis called Africa palm oil which grows in Hawaii, Nigeria, Malaysia and Australia.. The nut from the palm tree has a husk-red colour indicating maturity for usage. It is very fatty and edible. Palm kernel shell ash is an agro-waste in palm oil mills. It is the hard endocarp covering the palm kernel and is produced when the nut is cracked with a machine or manually using a stone. The Palm kernel is exposed after the palm oil have been extracted from the fruit. The physical appearance of PKSA is much influenced by the operating system in the palm oil mill. Properties of Palm kernel shell ash when refined include high strength, hardness, high wear resistance, high thermal strength and low co-efficient of thermal expansion.[8].

Table 1: Physical and Chemical Composition of Ash from PKSA

Property	**Parameter**	**Value wt (%)**
Physical	Moisture content	6.11
	Ash content	8.68
	Bulk density (Kg-m³)	9.24
	Porosity	65
Chemical Oxide	SiO_2	71
	Al_2O_3	7.6
	Fe_2O_3	4.6
	CaO	3.6
	MgO	2.6
	K_2O	5.6
	SO_3	2.0

Material Preparation

Zinc ingot and aluminum 6063 were used in preparation of ZA-27 (Zamak 27) alloy metal matrix. Chemically pure silicon carbide (SiC) with coarse particle size and palm kernel shell ash (PKSA) derived from burning and sieving of dry palm kernel shell was used as reinforcement. Six test samples with varying proportions of reinforcement according to charge calculation were produced.

Table 2. Elemental composition of zinc ingot

Elements	Zn	Fe	Cu
%	84.74	11.89	3.38

Table 3. Chemical Composition of Aluminium Ingot

Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Ni	V	Pb	Al
0.14012	0.52354	0.03862	0.00937	0.00564	0.04119	0.00683	0.00174	0.01355	0.01863	0.00739	99.1934

Preparation of the Agro Waste Material

The agro waste material (palm kernel shell) were obtained from a nearby local market at Ewekoro in Ogun state, Nigeria. The already dried solid shells were poured on a steel plate in open air then exposed to direct sun rays and left to dry for two (2) weeks until no sign of moisture was observed. The palm kernel shell ash was then burned vigorously at a temperature of about 550ºC into fine powder. 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 the temperature of 650^0c so as to reduce the carbonaceous and volatile constituents of the ash.

Preparation of the Zinc Ingot

The Zinc ingot was marked and sub-divided into 21 pieces with the aid of a chalk. The ingot was then drilled along the marked area to enhance cutting. A drill bit of size 10 was used on the pillar drilling machine for the drilling operation. After drilling, the ingot was then cut manually with a hack saw, 21 pieces were obtained as earlier marked. Five pieces weighing approximately 460kg were selected for the melting process.

Preparation of the Aluminium

The aluminum 6063 (window profile) were cut into pieces and it was weighed on a digital scale. Six samples weighing approximately 186.65g were selected for the melting process.

Preparation of Mould

This started with selection of pattern and molding box (cope and drag). All pattern used were single piece pattern both wooden and plastic. Cylindrical patterns were selected for the wear specimen while cylindrical patterns were selected for the torsion, microstructural and hardness specimen. After selection of pattern, the mould was then prepared. This started with collapsing of the previously made mould with the use of a shovel and hammer, the moulding sand was then conditioned with water and mixed, sieving of the facing sand inside the head pan. The drag was prepared, facing coming first, ramming after. Parting line was created along the side of the patterns to facilitate allowance for easy removal of pattern. Parting sand was applied on the face of the drag.

The cope was after then prepared creating cavity in it with the sprue pins. The materials used in preparation of the mould are; cope and drag, shovel, sieve, head pan, pattern, parting sand, moulding sand, water, bellow, hand trowel, rammer, and moulding board.

Table 4.charge calculation

Sample	**PKSA(%)**	**PKSA (g)**	**SiC(g)**	**Zinc (g)**	**Aluminium(g)**
A	-	-	13.80	469.10	186.32
B	0.2	1.38	34.60	469.50	186.70
C	0.4	2.76	34.50	467.00	186.52
D	0.6	4.15	34.56	465.97	186.66
E	0.8	5.53	34.50	464.96	186.80
F	1.0	7.00	35.00	472.0	189.00

Tensile Test

The tensile tests were carried out at the department of Materials and Metallurgical Engineering, Obafemi Awolowo University (OAU) Osun State using a Universal Tensile Machine.

Hardness Test

The hardness tests were carried out in the department of materials and metallurgical engineering Obafemi

Awolowo University (OAU) Osun State. Brinell hardness test was performed on the specimens using the universal hardness testing machine.

Microstructural Test

The microstructural tests were carried out at the department of Materials and Metallurgical Engineering, Obafemi Awolowo University (OAU) Osun State using a Computerized optical microscope.Test specimens were cut from the test materials [5 mm × 5 mm × 5 mm]. The specimens were mounted on a Bakelite thermosetting powder. Each specimen was ground with several emery papers of different coarseness, beginning with a coarse emery paper and ending up with a coarse emery paper. After grinding, the specimens were polished and then etched before the micro examination test.

RESULTS AND DISCUSSION

The raw data collected from the test experiment for this research are presented systematically in tables as shown below.

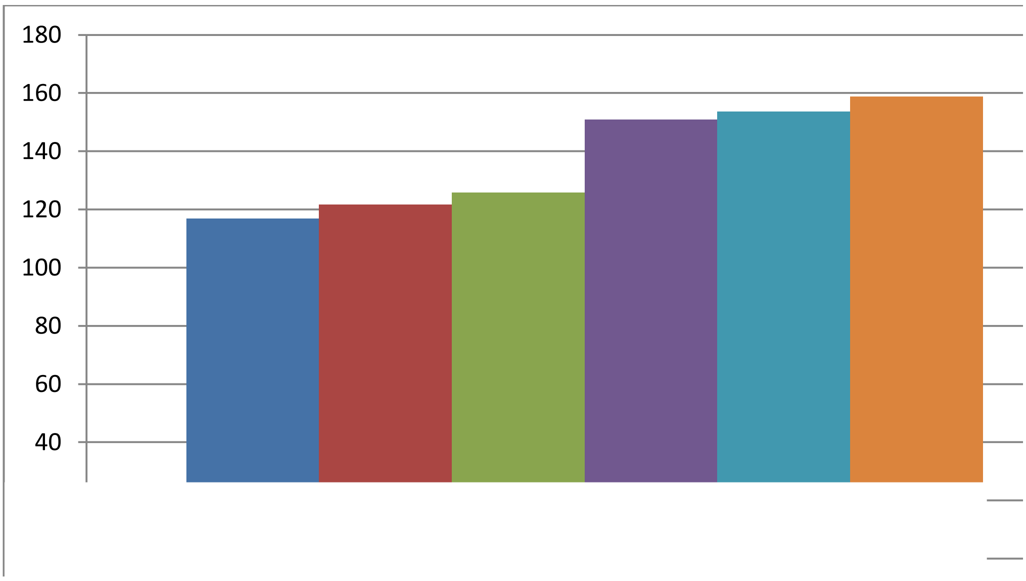
Tensile Test

Table 4 Tensile Strength

Sample	wt%PKSA	N/mm²
A	-	116.882
B	0.2	121.6389
C	0.4	125.7162
D	0.6	150.8594
E	0.8	153.577
F	1.0	158.674

The Tensile test for Zinc, Aluminium, SiC and PKSA for different samples of 0.2%, 0.4%, 0.6%, 0.8% and 1.0% shows that Tensile strength increases with increase in the weight percentage of PKSA.

Fig 1.1. shows the result of tensile test in bar form, it is observed that the tensile strength for samples B-F increases with increase in the weight percentage of PKSA,while the Control sample A which has no percentage of PKSA has the lowest tensile strength.



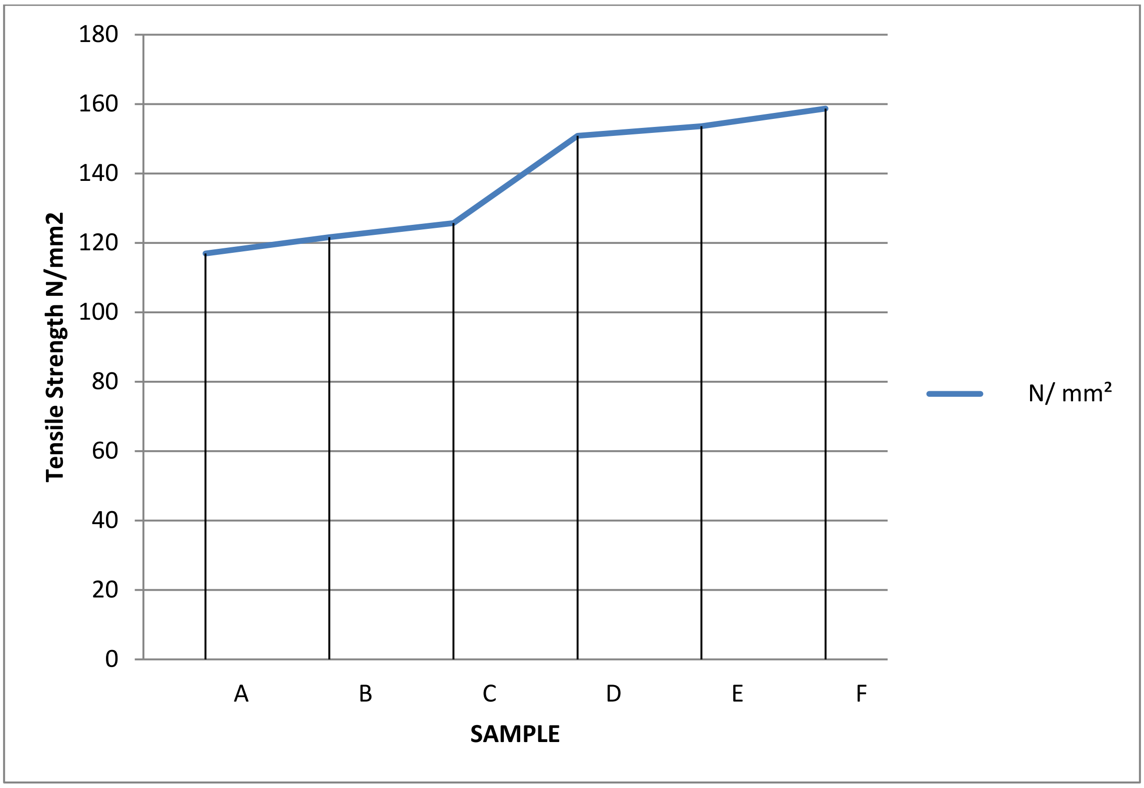


Fig 1.2. Graph for the tensile strength for each sample

Brinell Hardness Test

Table 5 Brinell Hardness test

Sample	**%**	**Hardness value(BHN)**
A	-	34.40
B	0.2	35.80
C	0.4	37.00
D	0.6	44.40
E	0.8	45.20
F	1.0	46.70

Fig 1.3. shows the result of hardness test in bar form,it is observed that the hardness for samples B-F increases with increase in the weight percentage of PKSA, while the Control sample A which has no percentage of PKSA has the lowest hardness.

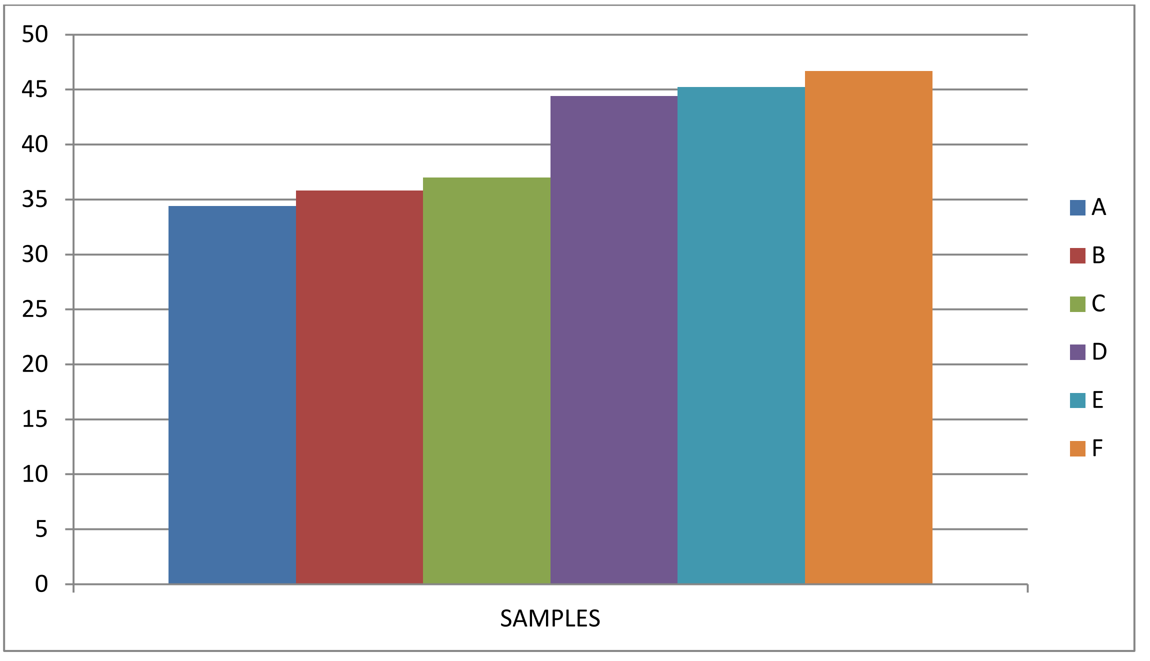


Fig 1.3. Histogram of the Hardness test

The Brinell hardness test for Zinc, Aluminium, SiC and PKSA for different samples of 0.2%, 0.4%, 0.6%, 0.8% and 1.0% shows that hardness increases with increase in the weight percentage of PKSA.

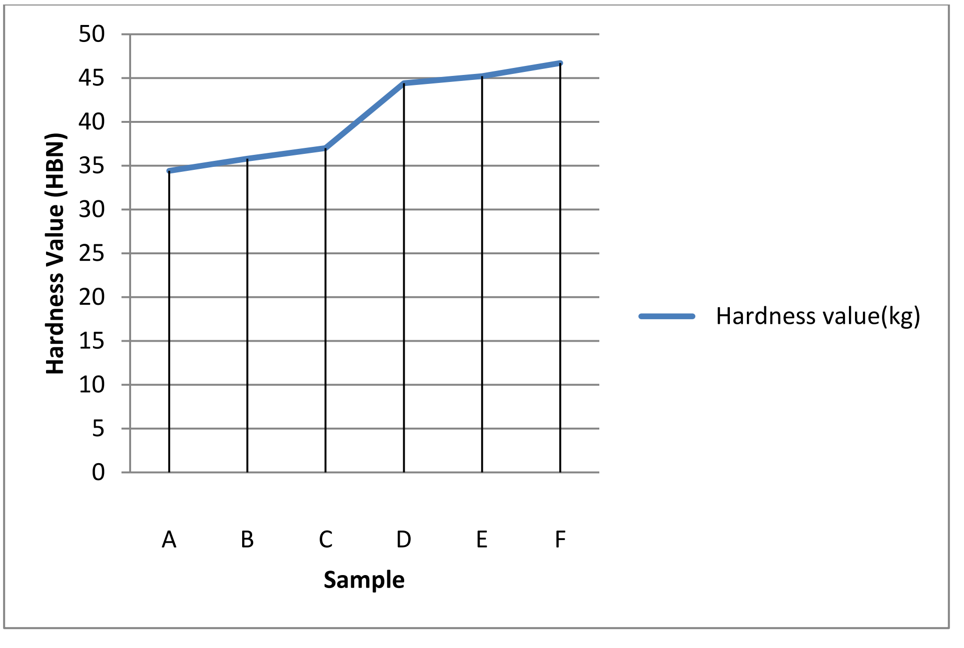


Fig 1.4. Graph for the hardness test for each sampless

COMPARATIVE ANALYSIS.

Fig 1.5. below shows a comparative analysis of both the results of the tensile strength and hardness test in a barForm, it is observed that the tensile strength and hardness of samples B-F increases with the increase of weight percentage of PKSA at a constant percentage of SiC(5%),while control sample A which has no percentage of PKSA included has a lesser tensile strength and hardness value when compared with samples B-F**.**

Sample F having the highest weight percentage of PKSA(1.0%) shows a result having the highest tensile strength and hardness and thereby gives best resistance to wear.

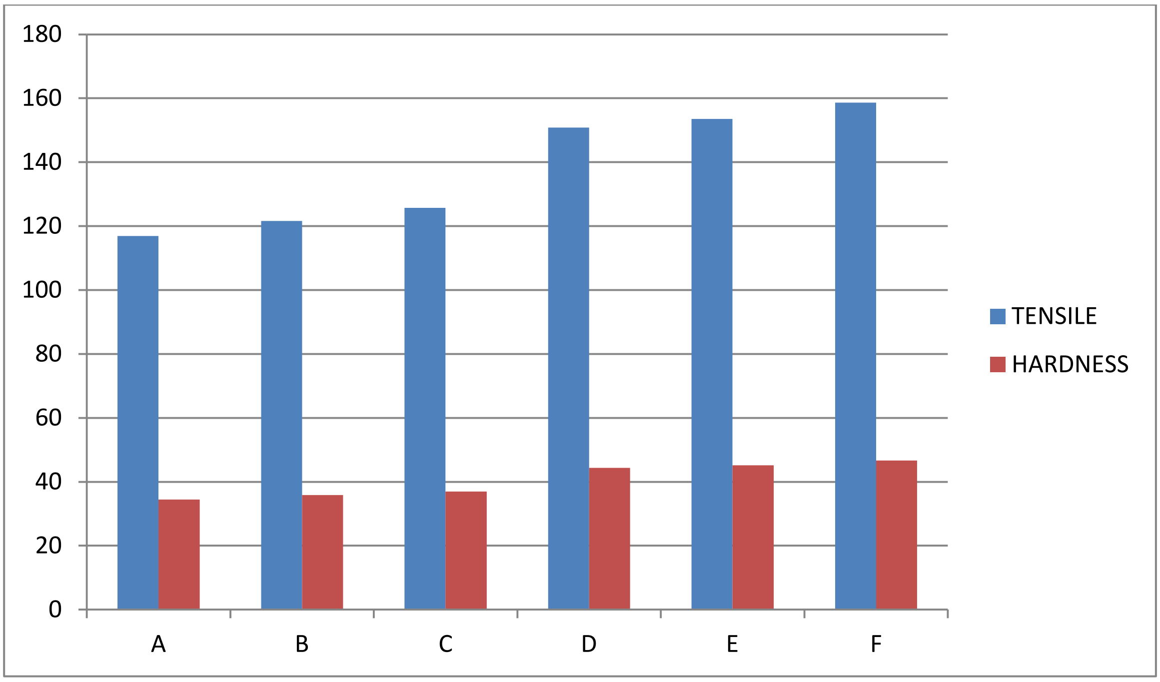
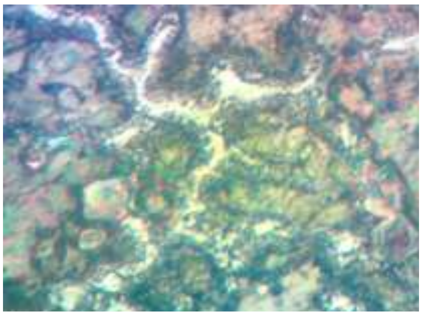
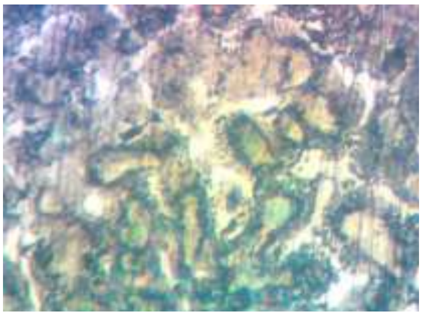


Fig 1.5. Histogram for the comparative analysis of the tensile strength and hardness on each sample.

Microstructural Analysis
Microstructures obtained from the computerized optical microscope are shown in figures below.





The micrograph of Control sample A shows a dispersed SiC(5%) in the matrix which results in a decline in its tensile strength and hardness due to the absence of PKSA,while sample B shows an increase in the hardness and tensile strength due to the addition of 0.2w% of PKSA in the matrix composite.

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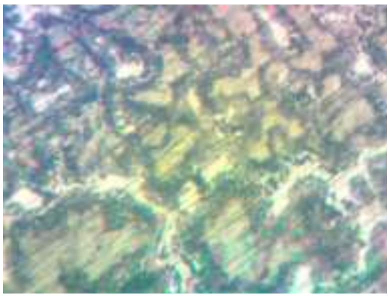
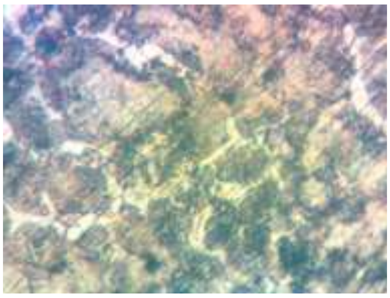


Sample E



Sample F

The micrograph of sample C,D,E and F with 0.4w%,0.6w%,0.8w% and 1.0w% PKSA shows a higher increase in hardness and tensile strength due to increase in w% of PKSA in each samples at a constant 5w% of highly dispersed SiC in the matrix composite. Micrograph of Sample F shows a highly dispersed PKSA(1.0) which gave rise to the highest tensile and hardness effect on sample F**.**

CONCLUSION AND RECOMMENDATION

Conclusion

This research work, among many has provided ways of converting commercial wastes, especially palm kernel shell which are posing environmental problems, to useful substances. From the analysis of results obtained during this study, the following conclusions were made:

1. The ultimate tensile strength of aluminum based metal matrix composite increases as the weight fraction of PKSA particles increases.

2. The elastic modulus of zinc based metal matrix composite increases as the weight fraction of SiC_p or PKSA particles increases.

3. The hardness of Zinc based metal matrix composite increases as the weight fraction PKSA particles increases.

4. The ductility of Zinc based metal matrix composite decreases as the weight fraction of PKSA particles increases.

Therefore with the observations made on the mechanical properties of Zinc-Aluminium metal reinforced with SiC and PKSA, PKSA can replace SiC if used as reinforcement material in Aluminium metal matrix composite to an extent.

Recommendation

Some mechanical properties of the composites were not obtained. It is therefore recommended that further test should be carried out to know the properties such as creep and fatigue strength of the material. This will help to recommend such materials for high temperature operations.

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