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Characterization of Coconut Shell Ash forPotential Utilization in Metal Matrix Composites for Automotive Applications

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ABSTRACT
Coconut shell ash is agricultural waste. The waste is produced in abundance globallyandposesrisktohealthaswellasenvironment.Thustheireffective,conduciveandeco-friendlyutilizationhasalwaysbeenachallenge for scientific applications.This paper mainly deals with identification of characteristics of coconutshellashusingspectroscopicandmicroscopicanalysis.Density,Particlesize,Refractoriness,SEM,XRD,XRF and FTIR spectroscopic methods were used for the characterization of the coconut shell ash. The resultswere compared and it was observed that the ash possesses nearly same chemical phases and other functionalgroups as reinforcement like fly ash, rice husk ash, bagasse ash that have been in Metal Matrix Composites(MMCs)specificallyforautomobileapplications.Hence,coconutshellashcanbeusedasalowcostreinforcementin MetalMatrixComposites (MMCs).

KeyWords: Density;microstructure;particlesize;refractoriness

I. INTRODUCTION

Researches all over the world today are focusing on ways of utilizing, either industrial or agricultural wastes as asource of raw materials for the industry. These wastes utilization would not only be economical, but may alsoresulttoforeignexchange earningandenvironmental pollutioncontrol[1-2]

Metal matrix composites (MMCs) posses significantly improved properties including high specific strengthspecific modulus, damping capacity and good wear resistance compared to unreinforced alloys[2-4]. Similarly,there has been an increasing interest in composites containing low density and low cost reinforcements. Amongvariousdiscontinuousdispersoidsusedareflyash,redmud,Ricehuskash[1-5]aresomeofthemostinexpensiveandlowdensityreinforcementavailableinlargequantitiesassolidwasteby-product.

Coconut shell is an agricultural waste and is available in very large quantities throughout the tropicalcountries of the world.Moreover, coconut is becoming an important agricultural product for tropical countriesaround the world as a new source of energy-biofuel[6].Previously, coconut shell was burnt as a means of solidwaste disposal which contributed significantly to CO2 and methane emissions [6]. However as the cost of fueloil, natural gas and electricity supply has increased and become erratic, coconut shell has come to be regarded assource 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 thecoconutshell asfuel material intheircastingandforgingoperations[6].

Bamgboyeand Jekayinfa[6] regretted that 90% of coconut (empty fruit bunches, fibers, fronds, trunks,shell) was discarded as waste and either burned in the open air or left to settle in waste ponds. This way thecoconut processing industries waste according to him contributed significantly to CO_2 and methane emissions.Based on economic as well as environmental related issues, efforts should be directed world wide towardscoconutmanagementissuesi.e.ofutilization,storageanddisposal.Differentavenuesofcoconutshellutilizationaremoreorlessknownbutnoneofthemhavesofarprovedtobeeconomicallyviableorcommercially feasible. Hence, the objective of this present work is to characterize coconut shellin order toexploreits useinmetalmatrix composites.

II. MATERIALS AND METHOD

Material

The coconut shell used in this work was obtained from a coconut seller in Kaduna, Kaduna state ofNigeria.Thephotographof thecoconutshellis showninPlate 1.

(a) Coconutshell (b)Crushedcoconutshell
Plate1:PhotographoftheCoconutshell.

Equipment
Equipmentusedinthisresearchare-electricalresistancefurnace,X-raydiffractometer(XRD),Scanningelectronmicroscopewithenergydispersivespectrometer(SEM/EDS)Machine,X-rayfluorescentXRF

Methods
Theprocessingofthecoconutshell(Carbonization)
The coconut shell was grinded to form coconut shell powder, the powder was packed in a graphitecrucible and fired in electric resistance furnace at temperature of 1300^{o}C to form coconut shell ash (CSAp)(seePlate2).

(a) Coconutshellpowder (b)Coconutshellash
Plate2:Photographofcoconutshellash

Particlessizeanalysis

Theparticlesizeanalysisofthecoconutshellashparticleswascarriedoutinaccordancewith BS1377: 1990[7].About 100g of the coconut shell ash particles was placed unto a set of sieves arranged indescending order of fineness and shaken for 15minutes which is the recommended time to achieve completeclassification. The weight retained on each sieve was taken and expressed as percentages of the total sampleweight.Fromtheweightretained, thegrainfinenessnumber(AFS)wascomputed[8].

DensityMeasurement

Density measurements were carried out on the coconut ash sample using Archimedes's principle. Thebuoyant force on a submerged object is equal to the weight of the fluid displaced. This principle is useful fordeterminingthevolumeandthereforethedensityofa nirregularlyshapedobjectbymeasuringits massinairanditseffective mass whensubmerged inwater (density =1gram/cc). Thiseffective mass under water was itsactual mass minus the mass of the fluid displaced. The difference between the real and effective mass thereforegives the mass of water displaced and allows the calculation of the volume of the irregularly shaped object. Themassdividedbythevolumethusdeterminedgivesa measureoftheaveragedensityofthesample[8].

Refractoriness

The Pyrometric Cone Equivalent (PCE) as recommended by ASTM Test C-24 was used in thedeterminationoftherefractorinessofthe sample[2].

MineralogicalCharacterizationoftheCoconutShellash

MiniPalcompactenergydispersiveX-rayspectrometer(XRF)wasusedfortheelementalanalysisofthecoconutshellash.Thesystemiscontrolledbya PCrunningthededicatedMiniPalanalyticalsoftware[8].

TheXRDanalysisofthecoconutshellashwascarriedoutusingPhilipsX-raydiffractometer.TheX-raydiffractogramswastakenusingCuKαradiationatscanspeedof3^{o}/min.Thesampleswererotatedat precisely one-half of the angular speed of the receiving slit, so that a constant angle between the incident andreflected beams is maintained. The receiving slit is mounted in front of the counter on the counter tube arm, andbehind it is usually fixed a scatter slit to ensure that the counter receives radiation only from the portion of thespecimenilluminatedbytheprimarybeam.Theintensitydiffractedatthevariousangleswasrecordedautomatically ona chartandtheappropriate(Θ) and(d)valueswerethenobtained[7-9].

MicrostructuralAnalysis

Themicrostructureandthechemicalcompositionsofthephasespresentinthecoconut shell ashwasstudiedusingaJOELJSM5900LVScanningElectronMicroscope equipped with an Oxford INCA^{TM}EnergyDispersiveSpectroscopysystem.The sample was placed on sample holder and the images werecaptured under various magnifications. Prior to it, sample was applied with the gold coating to avoid chargeeffect,sotoobtainclearimages.TheSEMwasoperatedatanacceleratingvoltageof5to20kV[2].

FourierTransformInfraredSpectroscopy(FTIR)

FTIR-8400S Fourier transform infrared spectrophotometer (SHIMADZU) was used for the functionalgroupspresentinthe coconut shell ash. Spectrometer and detector, capable of measuring functional group tothe predetermined minimum detectable level. The system include a personal computer with compatible softwarethatprovidesreal-timeupdatesofthespectralprofileduringsamplecollectionandspectralcollectionusingFTIR system using 1 cm^{-1} resolution, 22 meter path length, and a broad band MCT detector. The Data analysiswasperformedusingappropriatereferencespectrawhoseconcentrationscanbeverifiedusingCTSspectra[7].

III. RESULT AND DISCUSSION

From the particle size analysis results, it isshown that, the coconut shell ash has a Grain Fineness Number(GFN) of 75.08.The sample can be considered to be fine as GFN value of 100 is ranked the finest. Also, thesample can be considered to have met the AFS specification since four sieve-size, has the bulk of the retainedsampleonfourconsecutivesievescorrespondingto355µm,180µm,125µm,and63µmsizefractionsrespectively[2].

The density of the coconut shell ash is 2.05g/cm^3 which means that coconut shell ash is very light material.The value obtained fall within the range of density offly ash, bagasse andsilica which is 1.8 and 2.2 g/cm^{3}respectively[1, 2]currently used inmetalmatrix compositesThe coconut shell ash was observed to have Seger Cone No. 22, with equivalent temperature of 1500^{o}C.Thismeanscoconutshellashcanwithstandoperatingtemperatureof1500^{o}Cwithoutload[1-4].

The XRD pattern(see Figure 1) obtained reveal that, the major diffraction peaks are20.75°,10.22° and35.40^{o} and their inter-planar distance, 3.87Å, 8.66 Å and2.54Å, and theirrelative intensityofX-

rayscatteringare100.00,61.90and8.44andphasesat these peaks as Quartz(SiO_2),Cordierite, syn ($Mg_2Al_4Si_5O_{18}$)andMoissanite(SiC),whileeachof these phaseshaveascoreof44,32and16respectively(seeTable1).

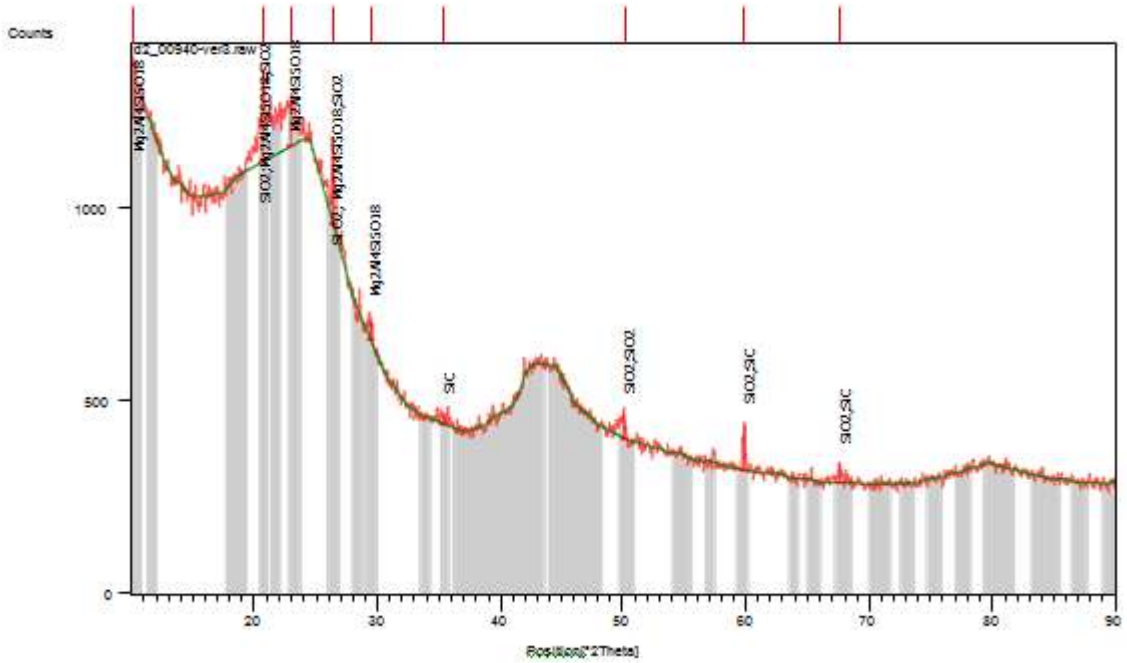


Figure1:XRDpatternofCoconutshellash

Table1:Identifiedpatternslistofcoconutshellash

Visible	Ref.Code	Score	CompoundName	Displacement [°2Th.]	ScaleFactor	ChemicalFormula
*	00-043-0596	44	SiliconOxide	0.000	0.912	SiO_2
*	00-013-0294	32	Cordierite,syn	0.000	0.590	$Mg_2Al_4Si_5O_{18}$
*	01-089-1961	26	Quartzlow, dauphinee-twinned	0.000	0.642	SiO_2
*	01-075-1541	16	Moissanite 6\ITH\RG	0.000	0.207	SiC

TheresultsshowedthatSiO_2hasthehighestpercentageofallthecompoundandelementpresentasrevealedbytheXRDanalysis.CompleteMineralogicalanalysiscarriedoutbyX-raydiffractionalso revealedthat the ash contains each of these elements C,O, Mg, Al, Si" Fe, Na, K, Zn and none of theseelementsH,He,Li,Be,B,N,F,Ne,P,S,Cl,Ga,Ge, As,Se,Br,Kr,Rb,Sr,Y,Nb,Mo,Tc,Ru,Rh,Pd,Ag, Cd,In,Sn,Sb,Te,I,Xe,Cs,Ba,La,Ce,Pr,Nd,Pm,Sm, Eu,Gd,Tb,Dy,Ho,Er,Tm,Yb,Lu,Hf,Ta,whichmeans that with the absence of all these other elements the coconutshell ash may not contain radioactivematerials. This is in par with the earlier of other biomass by[1-2]. The XRD result showed that both SiO_2andSiChaveafinestructure,theformerhavingafinerone.This couldbeassociatedwithporesize [2].

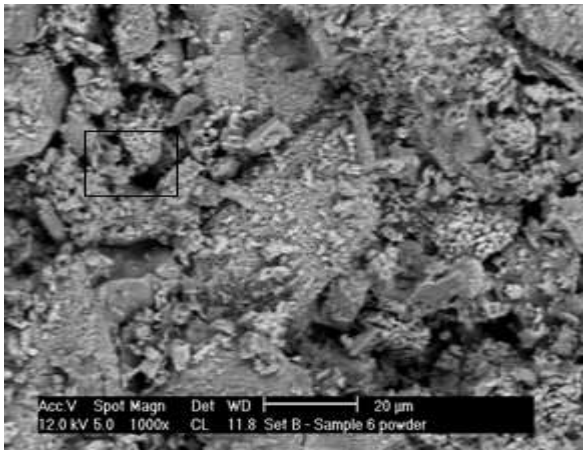
The XRF chemical composition of the coconut shell ash is represented in Table 2.XRF analysisconfirmed thatSiO2, Al2O3, MgOandFe2O3werefoundtobemajorconstituentsofthe ash.Silicondioxide, iron oxide and alumina are known to be among the hardest substances. Some other oxides viz. CaO,K2O, Na2O and MnO were alsofoundto be present intraces.The presence of hardelementslikeSiO2,Al2O3 a n dFe2O3 suggestedthat, the coconut shell ash can be use asparticulate reinforcement in variousmetal matrixes. This result of XRF is in agreement with the result of XRD obtained. Therefore, the

presentwork suggests the possibility of using coconut shell ash as particulate in metal matrix composites since thechemical composition has close similarity with the XRF analysis of rick husk ash, bagasse ash and fly ashcurrentlyusedinmetalmatrix composites[1-4].

Table2:XRFanalysisofCoconutshellash

Element	**Al_2O_3**	**CaO**	**Fe_2O_3**	**K_2O**	**MgO**	**Na_2O**	**SiO_2**	MnO	ZnO
%	15.6	0.57	12.4	0.52	16.2	0.45	45.05	0.22	0.3

Particle Morphology of coconut shell ash can be seen in back scattered electron (BSE) as shown inFigure 2.Coconut shell ash particles were observed to be solid in nature, but irregular in size. Somespherical shape particles can also be seen in the Figure 2.The chemical analysis of the coconut shellash morphology consists mainly of Si, C, O, Mg, Al with small amounts of Fe as shown in the EDSscan(seeFigure2).Theresultsareconsistentwit hXRDandXRFanalysisofotherbiomassby[1-5].



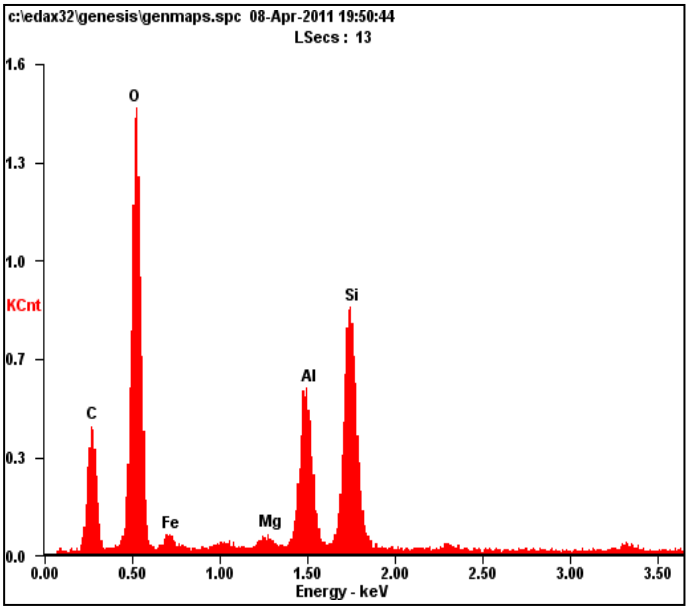


Figure2:SEM/EDSspectrumofCoconutshellash

Mainly twenty peaks were detected in the FTIR Analysis of the coconut shell ash as visible in Figure 3.These peaks are shown in Table 3. This result has shown that the presence of quartzinthe

originalashgivesriseinthe IR spectrum toa series of bandslocatedat 1132 and443.64cm^{-1}.Thepresenceofmullite,inturn,is responsibleforaseriesof bandsat around 3797 cm^{-1}. The presence ofcarbon group is present inseriesofbandsat around 4091.15-4617.74 cm^{-1}. Quartz, mullite and the vitreous phase of the ash overlap inthe areabetween1220cm^{-1}and1434.12cm^{-1}.HenceQuartz,Mullite,carbonandvitreousphasesare confirmed to be present. More over the peaks in treated and untreatedcasesdoes notshowany variations.Thisisinagreementwiththeearlierwor kof[4,9].

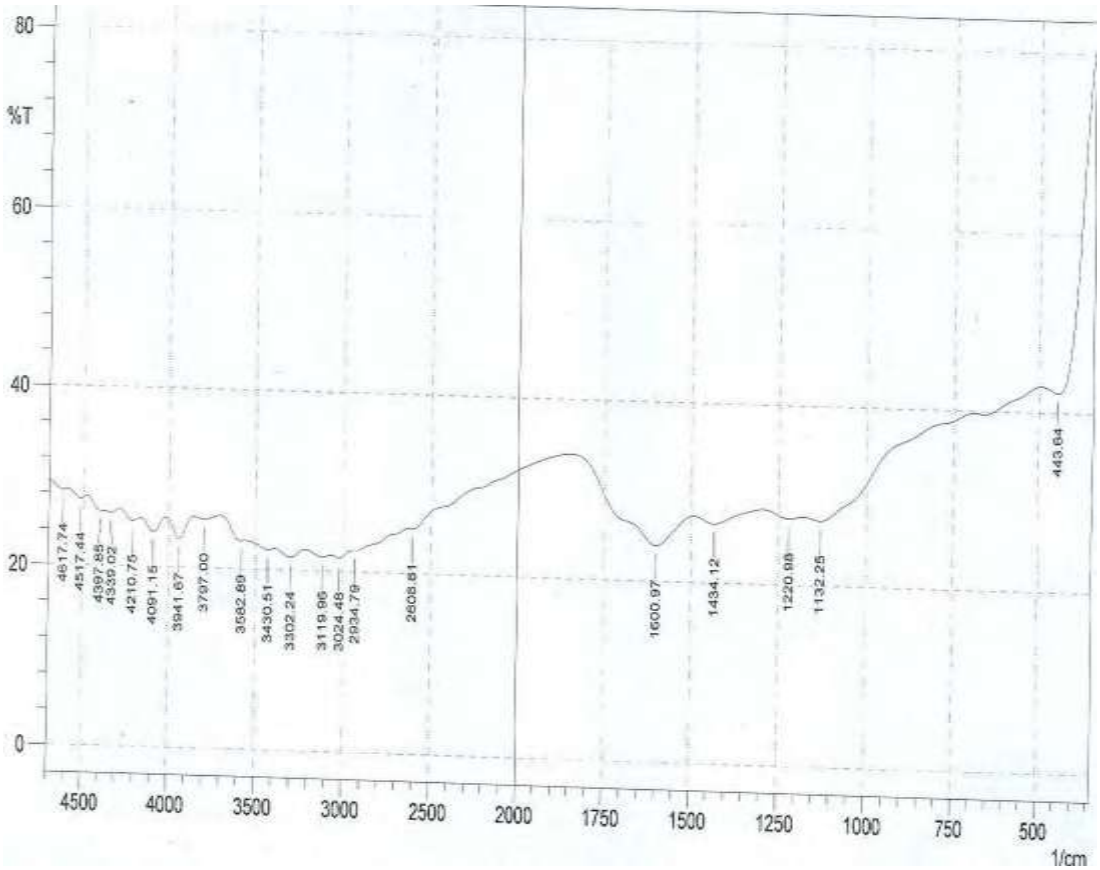


Figure3:FTIR spectrumofCoconutshellash

Table3:IdentificationPeaksoftheFTIRanalysis

	Peak	Intensity	Corr. Intensity	Base (H)	Base (L)	Area	Corr. Area
1	443.64	42.2149	13.1434	494.76	339.48	45.9051	10.1546
2	1132.25	27.1942	1.5636	1179.51	692.47	231.179	2.8009
3	1220.98	27.3523	0.4785	1296.21	1180.47	64.5302	0.4347
4	1434.12	26.5234	1.1098	1492.95	1297.17	110.3001	1.5246
5	1600.97	23.953	5.3532	1848.83	1493.92	198.1139	14.825
6	2608.81	24.9016	0.268	2630.03	1849.8	414.8633	0.2683
7	2934.79	22.3717	0.082	2944.44	2630.99	196.7375	0.5234
8	3024.48	21.4832	0.5261	3070.78	2945.4	82.8073	0.5844
9	3119.96	21.5287	0.4499	3218.34	3071.74	96.8457	0.6531
10	3302.24	21.4044	0.9435	3390.01	3219.3	112.6911	1.6016
11	3430.51	22.1843	0.3504	3553.96	3390.97	105.2941	0.4467
12	3582.89	23.0736	0.5718	3703.45	3554.93	91.4995	0.8093
13	3797	25.3657	0.3682	3854.87	3704.41	89.1332	0.5007
14	3941.67	23.1722	2.4099	4016.89	3855.83	98.5847	3.24
15	4091.15	23.8574	1.5527	4165.42	4017.86	89.7741	1.9765
16	4210.75	24.9963	0.6758	4287.9	4166.38	72.2261	0.7304
17	4339.02	25.8493	0.3262	4381.45	4288.86	54.1344	0.3576
18	4397.86	26.0397	0.2859	4476.93	4382.42	54.2572	0.3228
19	4517.44	27.3549	0.5835	4588.81	4477.89	51.741	0.4816
20	4617.74	28.3067	0.3104	4700.68	4589.77	60.1765	0.3021

IV. CONCLUSIONS

Fromtheanalysisoftheresultsanddiscussiongivenabove,thefollowingconclusionscanbemade.

1) XRDanalysisofthecoconutshellashrevealsSiliconOxide:(SiO_2),Corderite,syn:($Mg_2AlSi_5O_{18}$),Quartz:(SiO_2) and Moissanite (SiC) as the primary compound with SiO_2 as thehighestpercentageof all thecompound and elementpresent.

2) XRF studies revealed the presence of hard element like SiO_2, Al_2O_3, MgO and Fe_2O_3as majorconstituentswhichcan beusedasparticulatereinforcementsinMMCsforautomobileapplications.

3) FTIR graphs showed that Quartz, Mullite and Vitereous, carbon phases were present in coconut shellashpowderandproposedtousecoconutshellashas particulatereinforcementinMMCs.

4) The coconut shell ash can withstand a temperature of up to $1500o^C$ with a density of $2.05g/cm^3$. Thatmeansthisashcanbeuseinproductionlightweight MMCscomponentwith goodthermalresistance.

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