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Powder metallurgy processing and characterization of recycled aluminium alloy/date seed composite for motorcycle lever application

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Abstract

This paper reported aluminium alloy/date seed particulate composite fabricated by powder metallurgy technique for motorcycle lever application. The resulting aluminium alloy powder of 125 μm particle size at different weight percent additions of 0, 5, 10, 15 and 20 wt% of 75 μm particle sizes date seed milled powders were uniaxially compacted at 200 MPa. The sintered green samples at 580 °C for 2 hours in muffle furnace were tested to evaluate the physical, mechanical and microstructure properties following standard procedures. Results of the fabricated composite were compared with original equipment manufacturer (OEM) and aftermarket motorcycle lever products. It was obtained that; density of the composites produced decreases with percentage weight increase in date seed addition from 2.71g/cm^3 for unreinforced aluminium alloy to 2.613g/cm^3 at 20 wt% date seed particulates additions. The peak ultimate tensile strength of 112.46 MPa, hardness of 63.00 BHN at 20 wt% DSP and impact energy of 78.00 J at 10 wt% of date seed additions were recorded as for peak strengths of the composite produced. The equivalent percentage increase in ultimate tensile strength and impact energy of the composite was 127.01, 13.39%, 137.86, 16.42% and 22.29, 7.33% relative to that of unreinforced alloy, aftermarket and original equipment motorcycle lever products respectively at 20 and 10 wt% date seed addition. Microstructure of the composites revealed a fairly uniform dispersion of date-seed particulate in aluminium alloy matrix. Hence, the study concluded that, aluminium alloy-date seed composite fabricated from powder metallurgy technique can replace both the original equipment manufacturer and aftermarket motorcycle lever component.

Keywords: Original equipment manufacturer, Aftermarket-parts, Aluminium alloy composite, Mechanical properties, Powder metallurgy, Motorcycle-lever

1. Introduction

It is of general believe that, quality of original equipment manufacturers (OEM) parts is no doubt higher and usually more durable as compare to aftermarket automobile components parts. However, the high cost of OEM parts and inability to sustain the increasing volume of automobile machines seeking for replacement for proper functioning had constituted the major challenge of increasing cost of parts replacement after the useful service life [1-3]. This limitation gives birth to aftermarket parts remanufacturing which has flooded the auto-spare part markets in most developing countries including Nigeria [4]. The consequence of which has made it difficult to distinguish between the quality spare parts from the fake one. Though aftermarket parts may be cheaper, but risky a times in term of safety as well as long-term maintenance costs which cannot be overemphasized. It is therefore, a likelihood of aftermarket spare parts resulting in both accidents and frequent replacement of leading to increase operation and maintenance cost [5]. This scenario has become a source of concern especially for motorcycle owners and operators due to frequent failure of some aftermarket parts like leather brake, motorcycle hub, motorcycle lever made from aluminium materials in Nigeria. Thus, replacing some of these parts with a low-cost metal matrix composite material suggests a possible panacea of the present challenge of aftermarket spare parts. This is due to improved physical and mechanical properties of composite material resulting in alternative materials with high stiffness suitable in applications such as aerospace, defense, structural, automobiles, marine and mineral processing industries [6-8].

Metal matrix composite (MMCs) are engineered combination of matrix material and ceramic hard phase as reinforcement using a solid, semi-solid or liquid state processing route to produce a desired tailorable property [8]. Different materials can be used as matrix materials for the development of a new composite material but particulate-reinforced aluminium alloy MMCs are mostly use in industry due to their low density, enhanced mechanical properties, high corrosion resistance and reasonable cost [9-12]. Compo-casting, stir casting and squeeze casting are some of the conventional processing techniques usually use in the production of metal matrix composites due to their simplicity and low cost of processing. However, they are not without their limitations of poor wettability between the matrix and reinforcements, agglomeration of the reinforcement in the matrix alloy and high temperature involvement as well as oxidation problem [7, 13, 14].

Powder metallurgy is a solid-state metal processing technology in which components are produced from metallic powders by compaction into desired green shape followed by sintering below the melting point of the matrix-based metal to

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Figure 1 Waste aluminium can

Figure 2 Date-seed

cause solid state bonding of the loose compacted green sample into a hard and strengthened part. This technique inhibits the problem of poor wettability and enhance the uniform dispersion between the reinforcement and matrix metal powder due to proper solid-state mixing of the constituent powders from ball milling and as well as prevention of unwanted oxides which are very difficult to control in liquid processing route [14]. Therefore, many works have been found in literature on powder metallurgy processing route on both the physical and mechanical properties of aluminium alloy composite.

Purohit et al [15] studied the mechanical properties of Al-SiCp composites with 5 to 30 wt% of SiCp using powder metallurgy process. The density, porosity, hardness, compressive strength and indirect tensile strength of Al-SiCp composites were found to increase with increase in the wt% of SiC from 5 to 30%. The improvement in mechanical properties was attributed to uniform dispersion of SiC particles in the aluminium matrix by mechanical alloying of powders as detected from microstructural examination. Furthermore, Bajpai et al [16] investigated the mechanical properties of powder metallurgy processed Aluminium-nano SiC composites. Their findings revealed optimum properties at 2 wt% of nano-silica particle addition beyond which a decrease in mechanical properties was observed. The decrease in properties was attributed to agglomeration at higher percent of reinforcement materials. The outcome of the critical review of the influence of powder metallurgy processing of alumina and silica-carbide on 2xxx series aluminium alloys as reported in the work of Ashwath and Savior [14] revealed that, alumina exhibits better strength to microstructure relationship with comparatively good tribological performance of SiC as reinforcement. It was further substantiated that, addition of ceramic reinforcements with less than 10 wt% threshold weight percentage addition can display excellent properties with no compromise in tribological and microstructural behavior. This assertion was in accordance with the result obtained by Oscar et al [17] where hardness increases from 24.4 to 123.84 HV when AA212 aluminium alloy was reinforced with 10 wt% SiC via a powder metallurgy route.

In the present days, lightweight, improvement in strength and low-cost are the main goals, for increasing the use of composite materials in various industries. Consequently, suitable industrial and agro-waste reinforcements such as fly-ash, coconut shell, bamboo leaves, date-seed and corn-corb ash have widely been investigated in aluminium matrix composites as a means of meeting the aforementioned target of now a day's technology driven requirements [18]. However, most of these works employed the liquid processing route and powder metallurgy processing of aluminium-agro waste reinforced composites are rarely found in literature. Date-seed as earlier reported [18], is an agro-waste by-product which has been constituting environmental nuisance in many parts of the world including Tunisia and Nigeria after the fleshy part of it has been removed. Results of aluminium/date-seed composite processed by liquid processing technique with increase in mechanical properties of the composite developed indicated that date-seed is a promising particulate reinforcement material for mechanical properties enhancement [18] . Furthermore, the increasing use of aluminium as beverages drinks packaging and consumption now a days is on the increase. The resulting of which has led to indiscriminate dumps of these aluminium can after the consumption and hence contributing to environmental degradation. Hence, there is need to recycle these waste materials into a more useful product that can bring economic propensity to the nations' economy. The aim of this paper is to produce and characterize recycled aluminium-date seed composite using powder metallurgy technique for motorcycle lever application.

2. Experimental procedure

2.1 Materials and equipment

Scraps of aluminium can (Figure 1) sourced from Ilorin, Kwara State, was used as matrix and date-seed collected from Kano, Kano State Nigeria shown in Figure 2 was used as reinforcement materials in this study. The major equipment used in this work include: BROCYER CLERO 13634T crusher, SNE FOUR A50 ball mill, MEMMET U30 electric oven, Crucible furnace, Scanning Electron Microscopy/Energy Dispersive Spectroscopy, WILD BARFIELD AD3405P electric furnace, Avery-Denison Universal Impact-Testing Machine and Testometric Universa Tensile Machine.

2.2 Aluminium Can scrap recycling and powder preparation

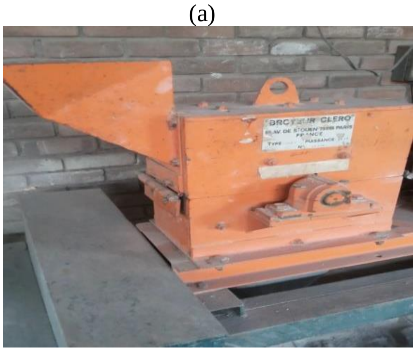
The waste aluminium cans were melted in a crucible furnace and stirred manually for 2 minutes to obtain compositional homogeneity after which it was deslagged three times to remove the impurities. The deslagged molten metal was poured into a mould to produce a cylindrical cast ingot (Figure 3a). Chips of cast samples in the form shown in Figure 3b were produced by turning on the lathe machine for easy crushing. The aluminium chips were crushed using BROCYEUR CLERO 13634T crusher displayed in Figure 3c. The crushed aluminium particles were then charged into SNE FOURE A50 ball mill containing steel balls of diameters ranging from 10 - 20 mm (Figure 3d). The milling operation was carried out in batches of certain amount of charges at the operating speed of the machine (55 rpm) for 4 hours after which it was subjected to sieving analysis to obtain the desired fine aluminium powders. This sequence was repeated to achieved the required amount Al powder used in this study.

2.3 Date-seed reinforcement particulate preparation

The date seed gathered from Kano, Nigeria was thoroughly washed with water to remove dust and any hard-sticky impurities.


(a)


(b)


(c)

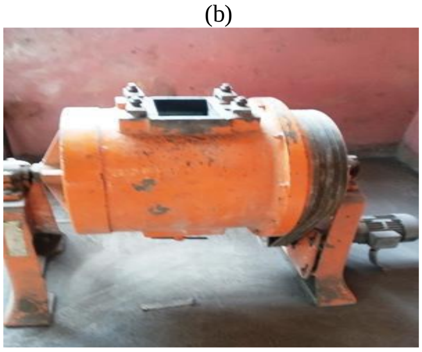
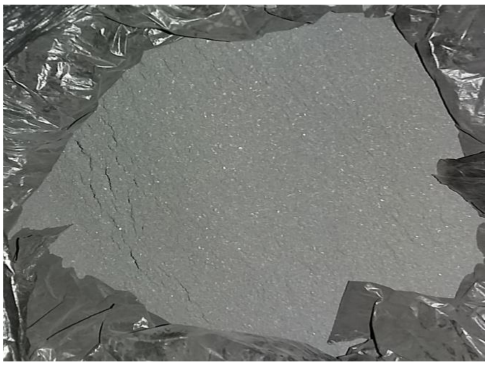

(d)

Figure 3 Procedure for recycling of aluminium can scraps: (a) cast ingot powder; (b) chips from cast ingot; (c) crusher and (d) ball mill


(a)

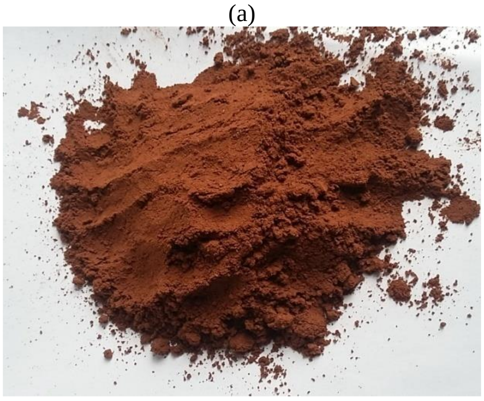

(b)

Figure 4 Powders of: (a) aluminium and (b) date-seed

It was then sun dried for 14 days and oven dried at 150 °C for 3 hours using MEMMET U30 electric oven to remove any remnant moisture. The dried date seed was crushed in BROCYEUR CLERO 13634T crusher. The crushed date seed particles were then milled into powder using SNE FOURE A50 ball mill at the machine speed of 55 rpm for 4 hours. Sieving of the obtained powder was then done to obtain the desire fine particle size.

2.4 Sieving analysis of aluminium and date-seed powders

Particle size analysis of aluminium (Figure 4a) and date-seed (Figure 4b) powders were carried using the technique of Aku et al., [19]. Sieve sizes were arranged in descending order of fineness from 300, 250, 200, 175, 125, 100 and 75 µm and placed on the vibrator. After tightly clamped, about 100g of the aluminium powder was placed on the largest sieve size and switched-on to shaken for 15 minutes. The aluminium powder retained at 125 µm sieve size was collected and used as matrix material in this study. The same procedure was adopted for the sieving analysis of date-seed powder. The powder retained at 75 µm sieve size was gathered and used as date-seed reinforcement material.

The EDS elemental compositional analysis of sample of aluminium and date-seed powders depicted in Figure 4 as used in this study were presented in Table 1 a & b. The compositional analysis in Table 1a indicated that, magnesium with 2.143 wt% amongst other elements is the major alloying element of the recycled aluminium scrap. Other elements such as silicon, iron, manganese and zinc are present in significant amount plus other minutes elements. This means that recycled aluminium can scrap used this work is close to 5xxx series of aluminium alloy. Table 1b gave the chemical composition of the powdered DSP with highest percentage of carbon (49.38%) and oxygen (30.53) contents balancing up with Na, Al, Cl and K at roughly equal amounts. The oxygen and aluminium suggest existence of alumina in DSP particulates coupled with high carbon content makes DSP a promising reinforcement in metal matric composites.

2.5 Production of aluminium-date-seed composite

The production of aluminium alloy-date seed composite produced at the ceramic department laboratory, Federal Institute of Industrial Research Oshodi (FIIRO), Lagos, Nigeria, by powder metallurgy method. Powder mixing of aluminium and date-seed powders at weight fraction of: 100: 0, 95: 5, 90: 10, 85: 15 and 80: 20 wt% aluminium and date-seed respectively were carried out using SNE FOURE 28A2092 Jar mixer operating at 95 revolutions per minute for 15 minutes for all combinations. Before the compaction of the loose blended metals powder, the

Table 1a Elemental composition analysis of recycled aluminium

Elements	Al	Mg	Si	Fe	Mn	Zn	Cu	Ti	Cr	K	Other
wt%	96.043	2.143	0.590	0.431	0.388	0.194	0.074	0.006	0.008	0.013	0.110

Table 1b Chemical composition analysis of date-seed powder

Elements	C	O	Na	Al	Cl	K	Others
Wt%	49.38	30.53	4.73	5.41	4.65	4.83	0.47

(a) (b) (c)

Figure 5 Aluminium date-seed composites at different stage of processing: (a) green compact, (b) sintering operation and (c) as-sintered composite samples

(a) (b) (c) (d)

Figure 6 Mechanical properties testing of aluminium date-seed composite specimen: (a) hardness sample, (b) impact energy samples, (c) tensile sample and (d) tensile testing

15 mm diameter cylindrical die mould wall cavity and die-punch's top was properly lubricated with wax. The various compositions of blended powders were compacted uniaxially on WEIBER P100HE electrically operated hydraulic press of 50 tonnes capacity at an applied pressure of 200 MPa for safety of the equipment used and quality of the green compacts in accordance with previous work [20], on a press speed of 6.2 mm/s and return speed of 8.3 mm/s for a holding time of 2 min. to obtain the green compact of composite sample as displayed in Figure 5a. The sintering of the green compacts was performed in WILD BARFIELD AD3405P electric furnace (Figure 5b) at 580 °C under 10 °C/min heating rate for 120 minutes in line with Nuruzzaman et al.,.[21] for good sintered samples. The samples were then furnace cooled to room temperature to obtain as-sintered aluminium date-seed composites (Figure 5c).

2.6 Physical and mechanical properties

The density, hardness, impact energy and tensile strength of the composites produced was determined as well as market and OEM motor-cycle lever part for the purpose of comparison.

2.6.1 Density determination

Densities measurements on the composite produced were carried out using Archimedes' principle. The weight of the composite in air and when fully submerged in water was performed on a table top digital weighing balance of 0.1mg precision. The density of the sample was then determined by Equation 1. Similar procedure was to determine OEM and aftermarket motor-cycle lever parts for comparison basis.

$$\rho_c = \frac{w_{ca}}{w_{ca} - w_{cw}} \times \rho_w \qquad (1)$$

Where ρ_c = density of the composite (g/cm^3), W_{ca} = weight in air of the composite (N), W_{cw} – weight in water of the composite (N) and ρ_w – density of water (g/cm^3)

2.6.2 Mechanical properties determination

The hardness of the samples (Figure 6a) was determined according to ASTM E10 standard on a Brinell hardness tester with indenter of diameter 10 mm and load 500kgf with dwelling time of 10 s. The average diameter of five indentations was used to determine the hardness number of the composite as given by Equation 2.

$$BHN = \frac{2F}{\pi D(D - \sqrt{D^2 - d^2}} \qquad (2)$$

Where *BHN* - Brinell hardness number, *F* - test force (Kgf), *D* – indenter diameter (mm) and *d* – average diameter of indenters (mm).

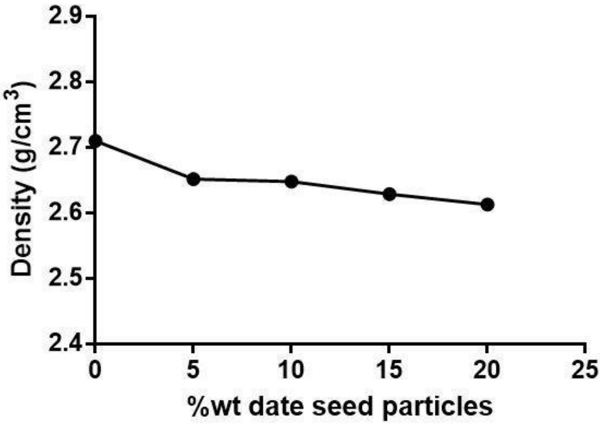


Figure 7 Density variation with date seed particulates addition

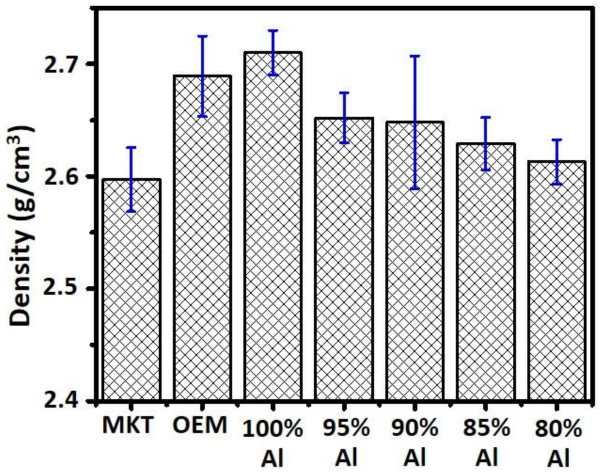


Figure 8 Density comparison for composite samples, OEM and aftermarket aluminium alloy

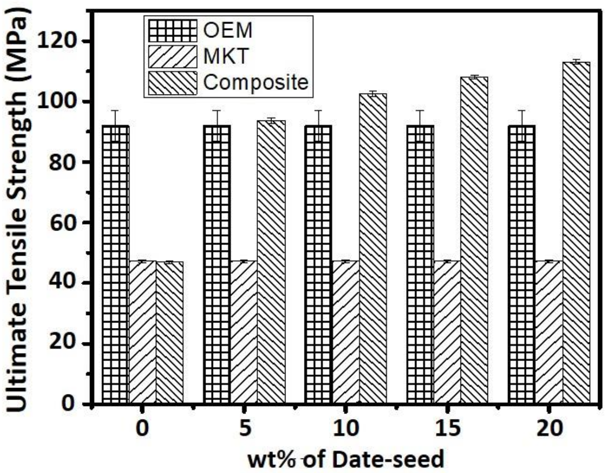


Figure 9 Tensile strength variation of aluminium/date-seed composites

3. Results and discussion

3.1 Physical property examination

The variation of density with varying weight percent of date-seed particulates addition in Al-alloy matrix as obtained from Equation 1 was as shown in Figure 7. It was observed that the density of aluminium alloy/date-seed composites decreased with increasing percentage by weight addition of date seed particles. For instance, the density of Al-alloy/date-seed composite decreased to 2.61 g/cm^3 at 20 wt% date-seed addition when compared to the density of unreinforced Al-alloy which is 2.71 g/cm^3 as discernible in Figure 7. This represents a 3.7% reduction in the density of the composite. The density reduction as obtained in this study was similar to that reported by Senapati et al., [22], where 2.52 and 2.46 density reduction was recorded using fly-ash and rice-husk as reinforcement respectively. This decrease in density was attributed to the low density of date-seed when compared with the density of aluminium alloy used as matrix. This translates into weight reduction of the resulting composite samples that are desirable in automobile application.

Composite samples for impact energy testing (Figure 6b) was prepared according to E23 ASTM standard. The notched cylindrical samples of dimensions 55 x 10 mm for Charpy impact examination was performed on Avery-Denison Universal Impact-Testing Machine with an initial energy of 30 Kgm hammer at a striking velocity of 5.24 m/s. The corresponding Impact energy at break measured in joules (J) was recorded for the test specimens. The tensile samples were prepared and tested according to B925 ASTM standard as shown in Figure 6c & d using Testometric Universal Tensile Testing machine. The test specimens were loaded at a constant crosshead speed of 5 mm/min. The tensile testing of three samples were done and average was used as the tensile strength of the composite samples.

The density of aluminium alloy/date seed composites produced were however compared with the densities of aluminium material used for OEM and the aftermarket sample used for motorcycle lever as shown in Figure 8. The comparison shows that the density of the unreinforced aluminium alloy and that of OEM aluminium material is the same while that of aftermarket sample is relatively lower. The density of the reinforced composites (0-20 wt% date-seed) can be seen to be lower compared to that of the unreinforced aluminium alloy and OEM aluminium material. Generally, the density of the aluminium alloy/date-seed composite is within the range of density of aluminium material used for motorcycle lever and it can be used for the motorcycle lever part.

3.2 Mechanical properties characterization

Mechanical properties characterization of the composites produced by powder metallurgy technique was made to determine the effect of the addition of date-seed particulate reinforcement in aluminium alloy matrix. The results were however compared with that of as-received OEM and aftermarket motorcycle lever aluminium material.

3.2.1 Tensile strength determination

The tensile strength of both unreinforced and reinforced aluminium/date-seed composites fabricated by powder metallurgy route with varying weight percent of date-seed particulates was as illustrated in Figure 9. It was observed that the addition of date-seed particles has significant influence on the tensile properties. The tensile strength increased with increasing wt% addition of date-seed particulates. For instance, the ultimate tensile strength of the aluminium/date-seed particulate composite increased from 46.89 MPa for un-reinforced aluminium alloy matrix up to 113.08 MPa at 20 wt% date-seed particulates addition. Also Figure 9 revealed 91.96 MPa and 47.28 MPa as the ultimate tensile strengths for as-received OEM and aftermarket aluminium alloy motor-cycle lever respectively under the same test conditions. This implies that, the OEM tensile strength is better than the aftermarket motor-cycle lever samples and unreinforced aluminium alloy. But upon reinforcing the aluminium alloy matrix phase with date-seed particulates resulted in increasing ultimate tensile strength of the composites up to 113.08 MPa which represents 141.2%, 139.2% and 23.0%

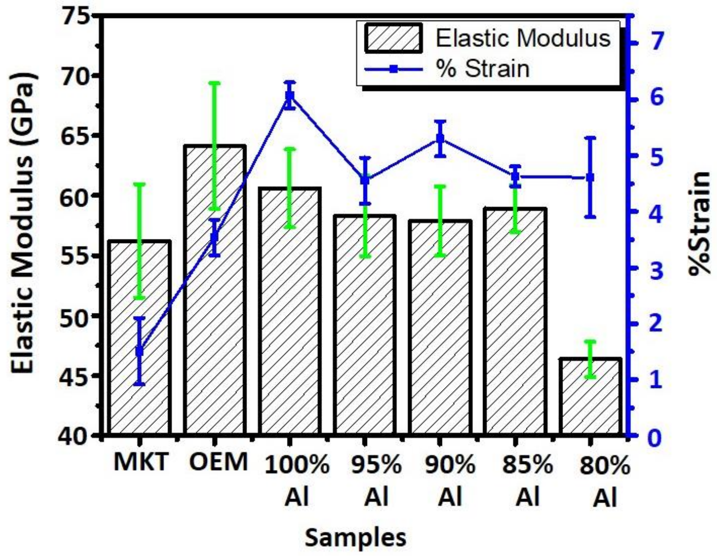


Figure 10 Elastic modulus and %strain of aluminium/date-seed composites

increase in ultimate strength with respect to unreinforced aluminium matrix, as-received aftermarket and OEM motorcycle lever respectively. This result is similar to that obtained by Bello et al., [23]; Bodukuri et al., [24] in which 63.64% and 58.47% increase in tensile strengths were reported using coconut shell ash and silica carbide respectively as reinforcement. The increase in ultimate tensile strength with increasing wt% addition of date-seed particles was attributed to the presence of carbon content in date-seed composition as shown in Table 1b results which were fairly distributed within the matrix with no observable macro-pores in the aluminium alloy matrix. Moreover, the presence of aluminium and oxygen in the form of alumina phase in DSP can enhance the composite strength due to its ceramic nature with high potentials as load carrier. Also, the addition of the date seed particles increases strength mainly by the load transfer from aluminium alloy matrix to the reinforcement due to the differences in the elastic modulus, thereby providing enhancing resistance to tensile stresses during loading. Furthermore, the sintering of the green compact enhances the grain refinement which reduces the grain size and the dendritic arm spacing of the grains thereby creating more grain boundaries in the alloy matrix which resulted in high dislocation density to inhibit plastic deformation. This is because, at such a high sintering temperature (580 °C), the DSP in the matrix is affected by oxidation which enhances mass transport (diffusion) of DSP via necking within the matrix for higher bond formation: hence increase strength. This result corroborates with the findings of earlier researchers [23-25] where tensile strength increases with increase in wt% of agro-waste reinforcement in aluminium matrix. It is worthy to note that, samples with higher percentage of date seed particulates exhibit largest tensile strength even though pores, agglomeration and microcracks were present. This characteristic behaviour of the composites can be explained from the perspective of reinforcement and pore formation. Increasing wt% of reinforcement can influence both the strength and porosity formation due to agglomeration which may impair composite strengths. Although, anyone of these parameters with higher index is presumed to determines the material strength behaviour. But in this study, reasonable distribution of the increase wt% of reinforcement and effective bonding at matrix-reinforcement interface as well as strain-hardening effect may be responsible for the increase in tensile strength despite some degrees of pores and microcrack noticed at higher DSP addition.

3.2.2 Elastic modulus and deformation behaviour evaluation

The elastic modulus and deformation measured in term of percentage strain of the market available (MKT) and original equipment manufacturer (OEM) motorcycle lever as well as date-seed reinforced aluminium alloy composites obtained from tensile tests were as charted in Figure 10. The results indicated that, the OEM elastic modulus (64 GPa) is higher than the MKT available (56 GPa) motorcycle lever. In addition, the elastic modulus of unreinforced aluminium alloy (60 GPa) was the highest and upon addition of date-seed particulates only decrease the elastic modulus of the resulting composites with the least magnitude (45 GPa) recorded in 20 wt% DSP reinforced aluminium alloy composites. It is worthy of noting that elastic modulus of materials is property measured within the elastic region which may not be insensitive to the ultimate tensile strength of materials. This implies that, as reinforced composite loses its ductility, the elastic modulus decreases as discernible in Figure 10 and similar to findings of Yuan et al. [26] in where the decreasing trend in elastic modulus was attributed to the materials damage with increase in load. Figure 10 also displayed that, the market available motorcycle lever had the least ductility amongst the OEM, recycled aluminium and the reinforced composites. The loss in the ductility of the reinforced composites as observed in this study can be attributed to the increasing addition of date-seed particulates in the aluminium matrix. The outcome of this findings agree with that reported by Madhusudan et al. [27] where agglomeration of the reinforcement had been held accountable for the loss in the composite ductility.

3.2.3 Impact strength test

Figure 11 shows the impact energy recorded during the experiment for aluminium alloy/DSP composites produced by powder metallurgy route compared with the OEM and aftermarket aluminium material used for motorcycle lever. OEM aluminium material has a slightly higher impact energy (72.82 J) compared to unreinforced composite (68.09 J) and aftermarket aluminium (67.43 J) lever material. But on addition of date seed particulates, the impact energy increased significantly compared to OEM and aftermarket aluminium material. The peak impact energy for the aluminium/DSP composite (78.00 J) was recorded at 10 wt% addition of DSP after which there was gradual decrease in impact energy up to 20 wt% date seed particulate addition. But the composite generally possesses a better impact energy property compared to OEM and aftermarket aluminium material hence the composite with 10 wt% addition of date seed particles can be recommended for applications where significant impact strength is required. This implies that the composites

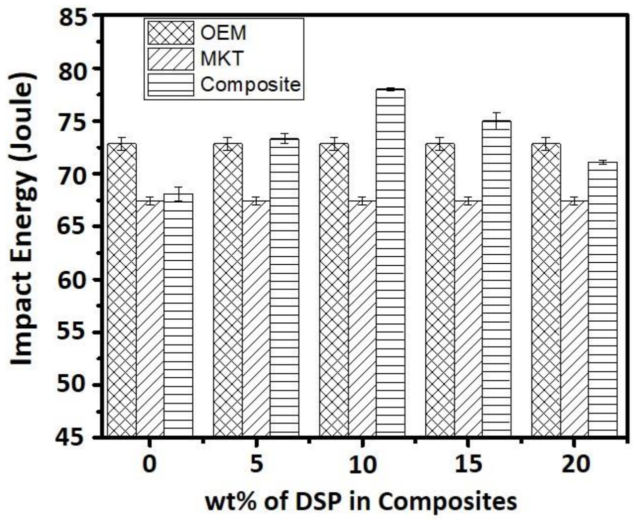


Figure 11 Variation of impact energy of aluminium/DSP composites with wt% of DSP

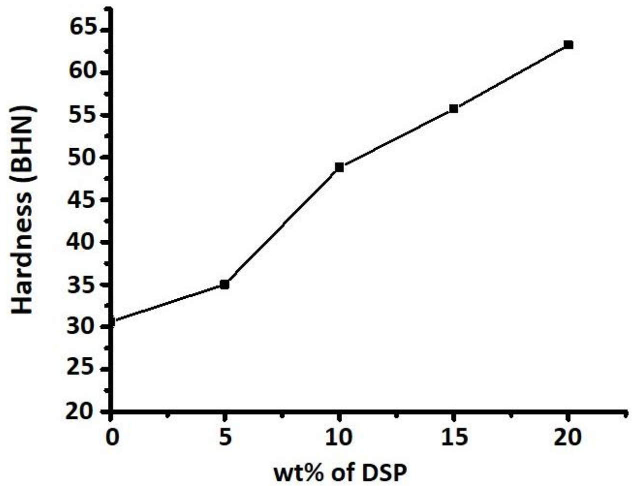


Figure 12 Variation of Al alloy/DSP composites with increase in wt% of DSP

produced can absorbed more energy before failure can set in. The increase in impact strength can be linked to good interfacial bonds between the matrix and reinforcements brought about by effectiveness of the milling process at low wt% addition of DSP. However, at higher addition beyond 10 wt% DSP in aluminium alloy matrix, the impact strength slightly decreases due to higher surface energy developed by higher wt% DSP addition in aluminium alloy matrix during the milling process, thus reduction in matrix-reinforcement interfacial bond. This result concurs with that reported by Kumar & Singh; Jeykrishnan et al.; Thirumalvalavan & Senthilkumar, [28-30] where the impact energy of various composite materials produced increased with increasing wt% of reinforcement up to particular limit beyond which it decreases.

3.2.4 Hardness

Hardness is defined as the resistance offered by the material to surface indentation and scratches which is a function of stress required to produce some specific types of surface deformation expressed in BHN (Brinel Hardness Number). The computed Brinel hardness results of the Aluminium/DSP composites as obtained from experimental testing were as depicted in Figure 12. It was observed that the hardness of the composite produced increased in a partial-linear form with increase in wt% DSP addition from 30.33 BHN for unreinforced alluminium alloy sample (at 0 wt% DSP) to a maximum of 63 BHN at 20 wt% DSP. Thus, all the composites specimens had higher hardness number compared to unreinforced aluminium alloy matrix hence, the composites have better hardness property suggesting for higher resistance to wear and scratchiness. These increments were attributed to increase in the weight percentage of hard and brittle phases of the date seed particles in the aluminium alloy. In addition, the increase in the interfacial contact area between the matrix and the reinforcement can be another reason for hardness increment of the composites. These findings correlate with the work of Abdulkareem et al; Thirumalvalavan & Senthilkumar; Meignanamoorthy & Ravichandran, [18, 30, 31] where they reported an increase in hardness of the composites with increase in wt% of the reinforcement.

3.2.5 Microstructure

Typical SEM microstructures of the both aluminium alloy matrix and composites produced with different weight fractions of the DSP using powder metallurgy technique, are as illustrated in Figure 13. The microstructure revealed that, unreinforced aluminium alloy matrix only possesses an alloy-phase morphology with two distinct phases depicting alloying dissolution in aluminium phase. With addition of 5 wt% DSP in aluminium alloy matrix, causes a change in the microstructure in aluminium with evolution of distinctive reinforcing phases which were fairly distributed within the matrix as discernible in Figure 13b. Although, some agglomeration of DSP was noticed in the microstructure of the resulting composite but no observable porosity or micro-crack found in 5 wt% DSP reinforced

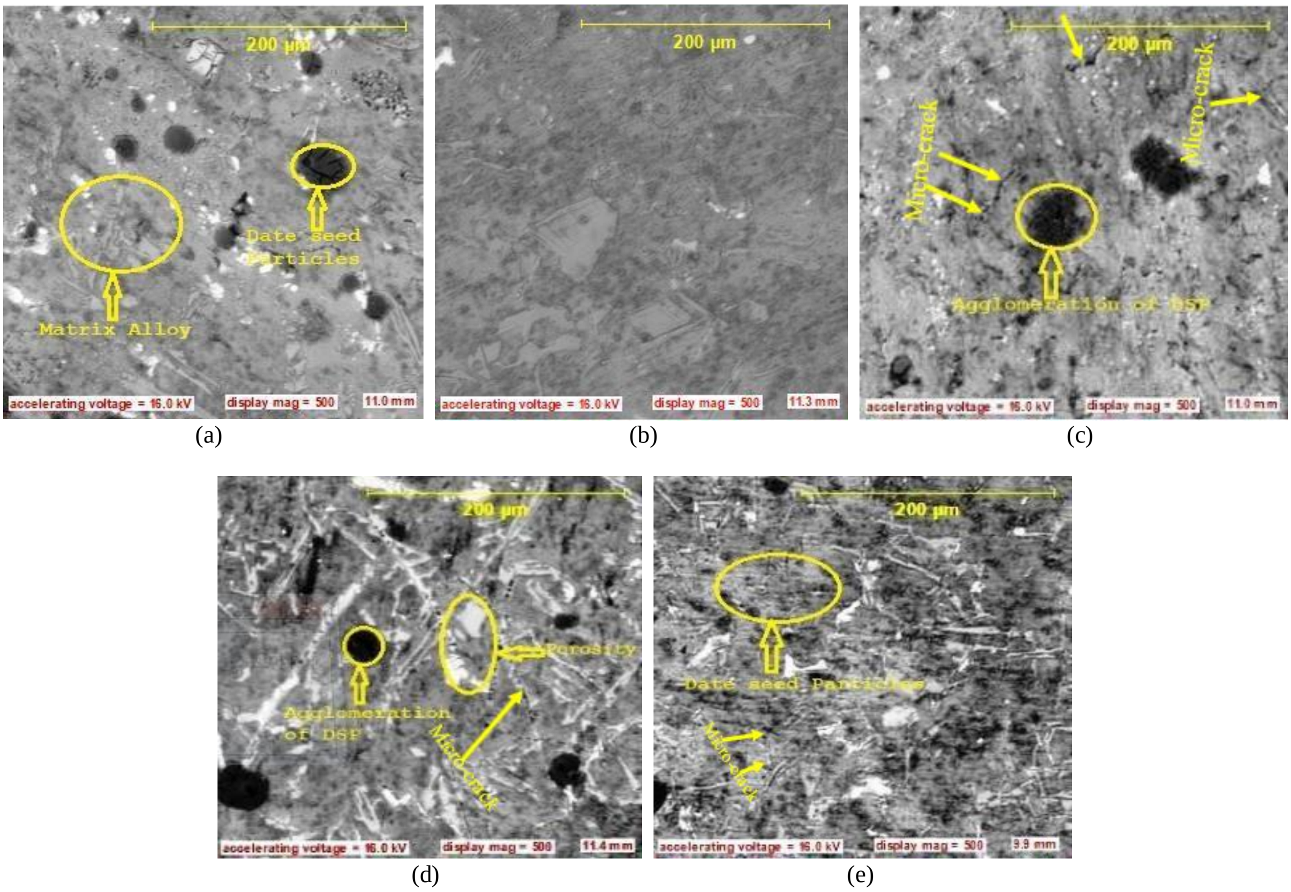


Figure 13 SEM micrograph of un-reinforced aluminium alloy (a) and 5 wt% (b), 10 wt% (c) 15 wt% (d) and 20 wt% DSP reinforced aluminium alloy composites

composite produced. The addition of 10 wt% DSP in aluminium alloy matrix resulted in microcrack and porosity formation as observed in Figure 13c. This observation was similar to that noticed in Figure 13 d and e when 15 and 20 wt% DSP were incorporated into the aluminium alloy matrix respectively. It was worthy of noting that addition of DSP at lesser wt% in aluminium matrix resulted into well distribution of reinforcements along the grain boundaries of the microstructures of the composites. The presence of porosity as observed from microstructural results (Figure 13) with higher wt% addition of DSP was attributed to increasing volume of reinforcement in the matrix with high surface energy beyond compaction force to achieve sufficient adhesion between the aluminium-alloy and DSP reinforcement particles coupled with agglomeration of DSP as evidenced from the surface morphology [32] and as well as the insufficient energy provided by the sintering process [33]. The homogenous distribution of DSP in the aluminium alloy matrix was responsible for the enhancement in the mechanical properties of Al-alloy/DSP composites in terms of hardness, toughness and tensile strength. This is possible because the DSP acts as load carrying member which was supported strong force of adhesion with aluminium alloy matrix.

4. Conclusions

In this study, date-seed particulate reinforced aluminium alloy matrix composites were produced with different wt% of DSP for motor-cycle lever application by powder metallurgy technique. The physical and mechanical properties of the produced composites were examined and compared with OEM and afetermarket motor-cycle lever. The following specific findings were that:

1. The addition of DSP in aluminium alloy matrix resulted in light-weight composites production with minimum density of 2.613g/cm^3 obtained at 20 wt% DSP additions;
2. The peak ultimate tensile strength (UTS) of 112.46 MPa, hardness of 63.00 BHN at 20 wt% DSP and impact energy of 78.00 J at 10 wt% DSP were recorded for Al-alloy/DSP composite.
3. The equivalent percentage increase in ultimate tensile strength and impact energy of the composite produced were 127.01, 13.39%, 137.86, 16.42% and 22.29, 7.33% relative to that of unreinforced alloy, aftermarket and original equipment motorcycle lever products respectively at 20 and 10 wt% date seed addition.
4. Motor-cycle lever part with matchable and/or enhanced physical and mechanical properties with original equipment manufacturer parts can be produced from date-seed particulates reinforced aluminium alloy composites via powder metallurgy route

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6. Conflict of Interest

The authors declared no conflict of interest.

7. References

[1] Mtanga S, Mccamel R. Motorcycle parts and aftermarket

industry regional value chains in South Africa. WIDER Working Paper 2019/38, UNU-WIDER. 2019:1-28.
[2] Uri D. Decision-making for strategic spare parts pricing levels : an evaluation of consumer products [dissertation]. Kingston: University of Rhode Island; 2014.
[3] Grondys K. Economic and technical conditions of selection of spare parts suppliers of technical equipment. Procedia Econ Financ. 2015;27(15):85-92.
[4] Black A, Makundi B, Mclennan T. Africa’s automotive industry: potential and challenges. Working Paper Series N° 282, African Development Bank. 2017:1-17.
[5] Smith K, Beard E. Disassembling assembler liability: are OEMs strictly liable for PMA parts in aviation cases?. J Air Law Commer. 2017;82(1):169-198.
[6] Idusuyi N, Olayinka JI. Dry sliding wear characteristics of aluminium metal matrix composites: a brief overview. J Mater Res Technol. 2019;8(3):3338-46.
[7] Manohar G, Dey A, Pandey KM, Maity SR. Fabrication of metal matrix composites by powder metallurgy: a review. AIP Conf Proc. 2018;1952(1):020041.
[8] Vani VV, Chak SK. The effect of process parameters in aluminum metal matrix composites with powder metallurgy. Manuf Rev. 2018;5:1-13.
[9] Cabeza M, Feijoo I, Merino P, Pena G, Pérez MC, Cruz S, et al. Effect of high energy ball milling on the morphology, microstructure and properties of nano-sized TiC particle-reinforced 6005A aluminium alloy matrix composite. Powder Technol. 2017;321:31-43.
[10] Rozhbiany FAR, Jalal SR. Influence of reinforcement and processing on aluminum matrix composites modified by stir casting route. Adv Compos Lett. 2019;28:1-8.
[11] Mangalore P, Akash, Ulvekar A, Abhiram, Sanjay J, Advaith. Mechanical properties of coconut shell ash reinforced aluminium metal matrix composites. AIP Conf Proc. 2019;2080:020014.
[12] Vinod B, Ramanathan S, Ananthi V, Selvakumar N. Fabrication and characterization of organic and in-organic reinforced A356 aluminium matrix hybrid composite by improved double-stir casting. Silicon. 2019;11(2):817-29.
[13] Mazen AA, Ahmed AY. Mechanical behavior of Al-Al2O3 MMC manufactured by PM techniques part I - scheme I processing parameters. J Mater Eng Perform. 1998;7(3):393-401.
[14] Ashwath P, Xavior MA. Processing methods and property evaluation of Al2O3 and SiC reinforced metal matrix composites based on aluminium 2xxx alloys. J Mater Res. 2016;31(9):1201-19.
[15] Purohit R, Rana RS, Verma CS. Fabrication of Al-SiCp composites through powder metallurgy process and testing of properties. Int J Eng Res Appl. 2012;2(3):420-37.
[16] Bajpai G, Purohit R, Rana RS, Singh Rajpurohit S, Rana A. Investigation and testing of mechanical properties of al-nano sic composites through cold isostatic compaction process. Mater Today Proc. 2017;4(2):2723-32.
[17] Oscar OO, de Araújo ER, de Lira HM, Gonzalez CH, Silva NDG, Urtiga Filho SL. Manufacturing of AA2124 aluminum alloy metal matrix composites reinforced by silicon carbide processed by powder metallurgy techniques of high energy ball milling and hot extrusion. Mater Sci Forum. 2017;899:25-30.
[18] Abdulkareem S, Edache EJ, Olowosule II, Ajiboye TK, Kolawole MY, Ahmed II. Effect of date seed particulates on mechanical properties of aluminium alloy. Acta Tech. Corviniensis-Bulletin Eng. 2018;11(2):89-94.
[19] Aku SY, Yawas DS, Apasi A. Evaluation of cast Al-Si-Fe alloy/coconut shell ash particulate composites. Gazi Univ J Sci. 2013;26(3):449-57.
[20] Feijoo I, Cabeza M, Merino P, Pena G, Rey P. Age hardening of extruded AA 6005A aluminium alloy powders. Materials (Basel). 2019;12:2316.
[21] Nuruzzaman DM, Kamaruzaman FFB, Azmi NBM. Effect of sintering temperature on the properties of aluminium-aluminium oxide composite materials. Int J Eng Mater Manuf. 2016;1(2):59-64.
[22] Senapati AK, Manas VS, Singh A, Dash S, Sahoo PK. Mechanical properties of mmc reinforced with waste materials. Int J Res Eng Technol. 2016;5(3):172-8.
[23] Bello SA, Raheem IA, Raji NK. Study of tensile properties, fractography and morphology of aluminium (1xxx)/coconut shell micro particle composites. J King Saud Univ - Eng Sci. 2017; 29(3):269-77.
[24] Bodukuri AK, Eswaraiah K, Rajendar K, Sampath V. Fabrication of Al–SiC–B4C metal matrix composite by powder metallurgy technique and evaluating mechanical properties. Perspect Sci. 2016;8:428-31.
[25] Mendoza-Duarte JM, Estrada-Guel I, Carreño-Gallardo C, Martínez-Sánchez R. Study of Al composites prepared by high-energy ball milling; Effect of processing conditions. J Alloys Compd. 2015;643(S1):S172-7.
[26] Yuan Z, Li F, Zhang P, Chen B, Xue F. Mechanical properties study of particles reinforced aluminum matrix composites by micro-indentation experiments. Chinese J Aeronaut. 2014;27(2):397-406.
[27] Madhusudan S, Sarcar MMM, Rao NBRM. Mechanical properties of Aluminum-Copper(p) composite metallic materials. J Appl Res Technol. 2016;14(5):293-9.
[28] Kumar D, Singh J. Comparative investigation of mechanical properties of aluminium based hybrid metal matrix composites. Int J Eng Res Appl. 2014:5-9.
[29] Jeykrishnan J, Vijaya Ramnath B, Hervin Savariraj X, David Prakash R, Dhinesh Rajan VR, Dinesh Kumar D. Investigation on tensile and impact behavior of aluminum base silicon carbide metal matrix composites. Indian J Sci Technol. 2016;9(37):2-5.
[30] Thirumalvalavan S, Senthilkumar N. Evaluation of mechanical properties of aluminium alloy (Lm25) reinforced with fused silica metal matrix composite. Indian J Eng Mater Sci. 2019;26(1):59-66.
[31] Meignanamoorthy M, Ravichandran M. Synthesis of metal matrix composites via powder metallurgy route: a review. Mech Mech Eng. 2018;22(1):65-75.
[32] Grigoriev SN, Dmitriev AM, Korobova NV, Fedorov SV. A cold-pressing method combining axial and shear flow of powder compaction to produce high-density iron parts. Technologies. 2019;7(4):70.
[33] Anil Kumar BK, Ananthaprasad MG, Gopalakrishna K. Action of Cryogenic chill on Mechanical properties of Nickel alloy Metal Matrix Composites. IOP Conf Ser Mater Sci Eng. 2016;149:012116.