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Ball Milling Synthesis of Al (1050) Particles: Morphological Study and Particle Size Determination

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Abstract
The milling characteristics of Al alloy containing 0.1% carbonised coconut shell was investigated. Milling duration up to 40 hours was adopted. Ball milling was carried out at 195 rpm of vial rotation and 8.5 charge ratios. Scanning electron microscope analysis was carried out before and after milling to study effect of ball milling on morphology and size of Al (1050) particles. Results revealed that a minimum particle size of 22.6µm was achieved. The synthesised Al (1050) particles can serve as initial powders for the synthesis of their nanoparticles and microfillers in polymer for polymer composite production for wear resistant and other engineering applications.
Keywords: Al (1050), Milling, Particle, Morphology, Sizes

1. Introduction

Bauxite has been a natural ore that contains alumina. Alumina is the mineral used for primary production of aluminium through a high energy consuming process. The process is associated with serious environmental impacts through the release of harmful gases that have negative influence on human life. Aluminium industry alone is responsible for 1% of global greenhouse gas emission [1]. Bauxite mining in Jamaica, Australia and India has caused serious problems to environment and social activities. This problem includes contamination of water and fishing supplies, the destruction of land and displacement of local communities.

The use of aluminium cans for drink and food packaging has been an alternative method to glass and plastic bottling system. Discarded aluminium cans dumped indiscriminately causes a new dimension of environmental concerns. Streets were littered with cans. Canals and culverts are blocked with cans, preventing the flowing of water. Many works have been focused on recycling of discarded aluminium products for development of aluminium based metal matrix composites for structural applications [2-6].

Globally, current advancement in material application in order to enhance the fuel efficiency of automobiles is the consideration of polymer matrix composites (PMC) for engine bay and EMI shield applications. PMC for such application requires incorporation of highly conductive metal particles to enhance their thermal conductivity and stability [7]. This has opened ways for researches in a new dimension. Aluminium alloy being very light and highly thermally conductive is one of the candidate metals suitable for the application. Since high energy consumption and environmental issues have placed barriers on continual dependence on primary production of aluminium from bauxite, a research for synthesis of aluminium particles from discarded aluminium products such as aluminium cans is very significant. Benefits of this attempt include reduction of the cost of production, safety against environmental issues from the primary production of aluminium, environmental cleanliness and wealth creation from wastes through a foreign exchange.

Ball milling can be defined as the application of friction, shear, impact and collision for structural and property modification. Excessive plastic deformation and strain hardening taking place during ball milling results in particle grinding and mechanical activation process. Particle structures are created in expense of bulk material structure due to impact of milling balls and vial inner wall on the bulk materials. This technique has been employed in powder metallurgy for the synthesis of micro or nanoparticles. An increment in the surface areas of the particles (mechanical activation) during ball milling prompts the chemical interaction between particles of different materials leading to intermetallic, alloy or composite particles for applications in engineering structures [8-13]. Particle synthesis via ball milling is influenced my many factors which includes brittleness of the bulk materials. The more brittle the material, the higher the degree of breakage. This implies that a brittle material such as iron will be broken much easier than soft/ductile material such as aluminium.

In this present work, Al (1050) particles have been synthesised via ball-milling from the cast of Al (1050) bars produced from aluminium cans. Aluminium being very ductile, tends to be gummy/flattening rather than breakage during the ball milling process. In order to enhance the breakage of Al (1050), about 0.1% carbonised coconut shell particles was added to the Al (1050). Aim of this work is to study effect of ball milling on particle sizes and morphology of Al (1050) particles. The synthesised microparticles could be used as microfillers for the production of polymer matrix composites or a sourced materials for the production of Al (1050) nanoparticles.

1.1 **Materials and methods**

Materials used in this study are aluminium cans, carbonised coconut shell and distilled water. Aluminium cans were procured from Waste Management Centre, University of Lagos, Nigeria. Carbonised coconut shell was synthesised by Bello (2015) [14]. Equipment used includes crucible furnace at Abiye Foundry Workshop, Bariga Lagos; Colchester/triumph lathe machine, model 2000 at Physics Workshop University of Lagos; 87002 LIMOGES planetary ball mill, model 28A20 92 at Ceramic Department, Federal Industrial Institute of Research, Oshodi (FIIRO), Lagos and scanning electron microscope (SEM), ASPEX 3020 and Baskar Optical Microscope (OM) at Kwara State University, Malete, Nigeria.

Al cans were remelted at 700°C using oil fired crucible furnace. Slag forming on the surface of the melt of Al cans were carefully screamed off. The melt was cast to obtain Al (1050) bars using a green sand mould. Al (1050) bars were split into fibres (Fig 1) using Colchester/triumph lathe machine. During splitting, jets of distilled water were introduced on the surface of the bars. This is to reduce the heat generated due to friction and harden the surface of Al (1050) bar in order to enhance their splitting.

A mixture of 500g of Al (1050) fibre, 0.5g of carbonised coconut shell and 4.25kg of ceramic balls of different diameters were placed in ceramic vial of the planetary ball mill and sealed. Al (1050)/carbonised coconut shell mixture was milled for 40 hours at an average daily milling duration of 5 hours. Figure 1 presents Al in different forms. Morphologies of Al (1050) before and after milling were examined using SEM and OM. Al (1050) containing 0.1% carbonised coconut shell particles were classified using set of sieves arranged in descending order of grain fineness number ranging from 600 to 75 µm. The sieve set was shaken for 15 minutes using sine shaker (see Figure 1e). Samples of Al (1050) particles retained in each sieve were analysed using Barska digital optical microscope having resolution of 640 x 840 pixels and 10-300 X magnifications.

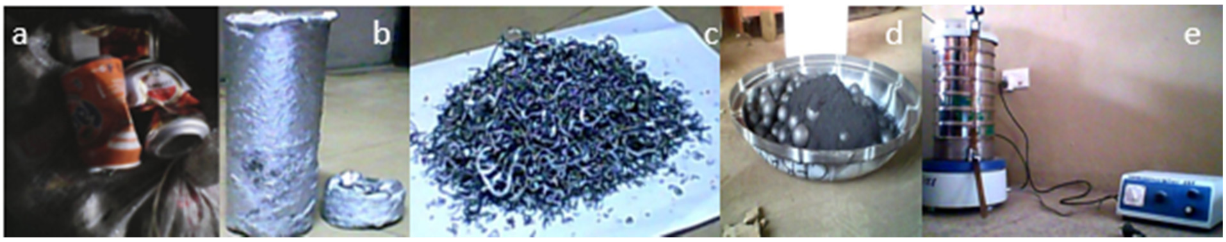

Fig. 1. (a) Al cans (b) Al bars (c) Al fibres (d) Composite particles (e) Sieve set

1.1.2 **Results and Discussion**

Result of particle classification analysis indicated that Al (1050) particles were retained in each sieve and the receiving pan placed below 75µm sieve. Figures 2a-b present the SEM micrographs of the Al (1050) fibre obtained from the machining process. Microstructure in Figure 2a presents large sized Al in continuous spiral fibres harbouring the smaller ones. The magnified micrograph as shown in Figure 2b displays polygonal fibres on top of a very large ones.

Effect of ball milling on the morphology of the Al (1050)/carbonised coconut shell particles can be seen by comparing micrographs in Figures 2- 3. There is a change in the particle appearance. Micrographs in Figure 3 appears brighter than those in Figure 2. It is observed from Figure 3 that the composite particles can be classified into big and small particles characterised with size variation. This agrees with results of sieve classification analysis. Size variation of the composite particles observed in Figure 3 can be interpreted by considering the Baskar optical micrographs of the Al (1050) particles retained in each sieve ranging from 600 to less than 75µm. Each micrograph in Figure 4 shows Al (1050) in flat polygonal shapes. Energy dispersive X-ray spectrograph of the Al (1050) particles (Figure 3) reveals the presence of Al with the highest count score (major element) and other elements such as carbon, oxygen, silicon, calcium, titanium and iron as minor or traced elements. Presence of carbon may be attributable to addition of carbonised coconut shell to Al (1050) which acted as process control agent. Size of the Al (1050) particles retained in the receiving pan was determined using software. Result obtained from the software is presented in Figure 5. It is observed from the result that the particle size varied between 22 and 75µm with an average size of 51.06µm.

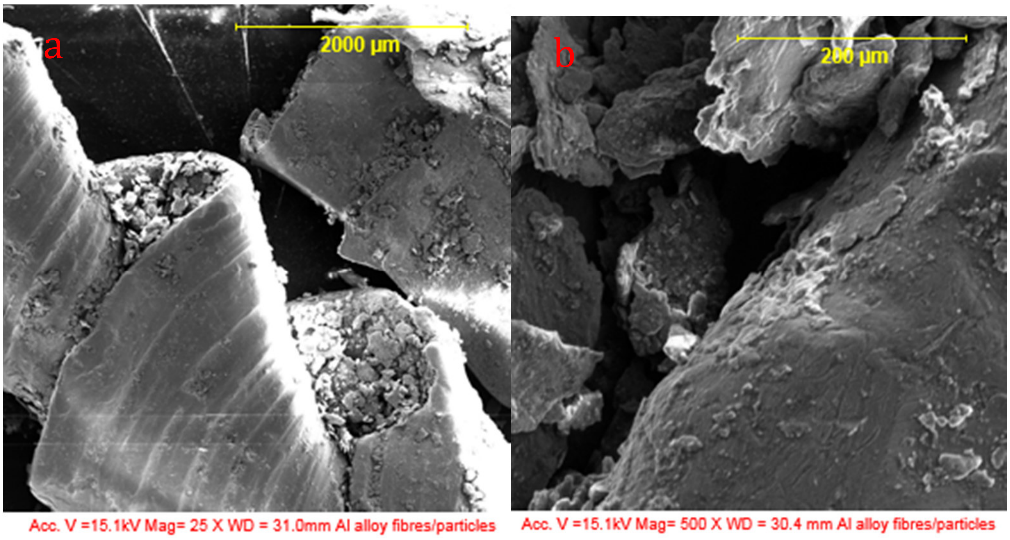

Fig. 2. SEM Micrograph of Al alloy fibres/particles (a) low magnification (b) high magnification

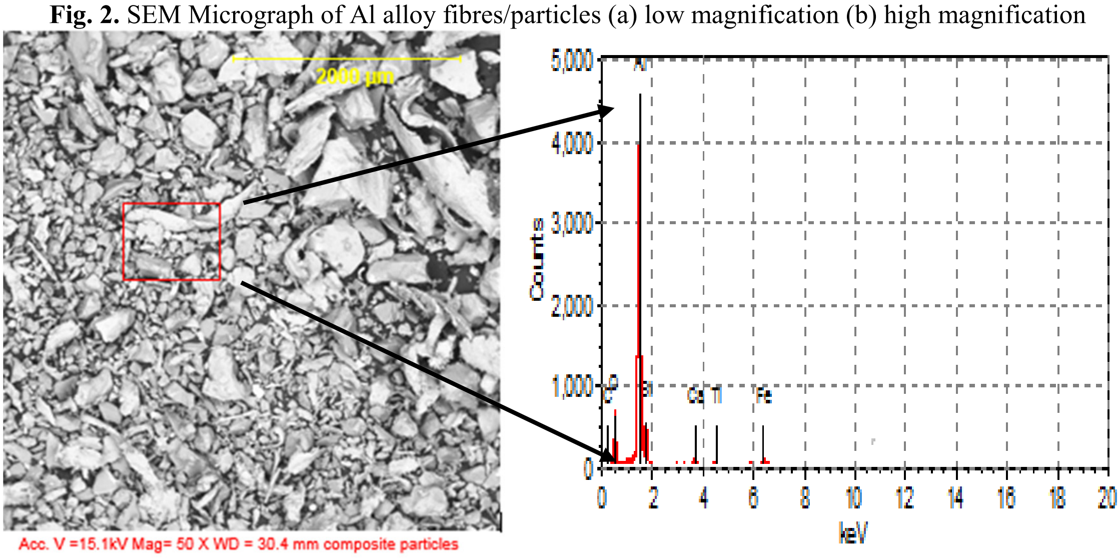

Fig. 3. SEM/EDS of Al alloy/coconut shell based graphite particles


a
200 µm
b
200 µm
c
200 µm
d
200 µm
e
200 µm
f
200 µm

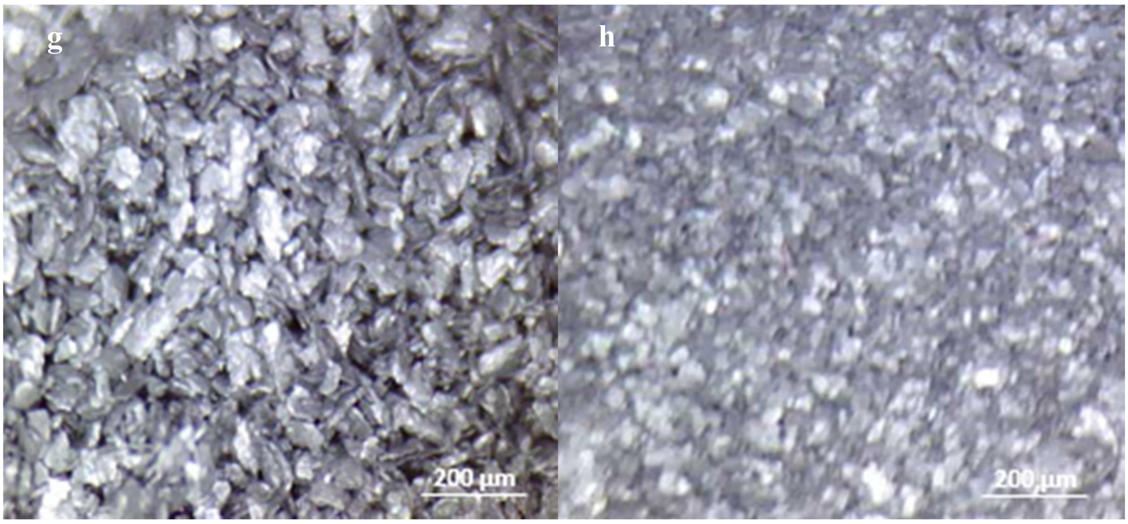

Fig. 4. Baskar micrographs of Al alloy/coconut shell based graphite particles retained in the (a) 600 (b) 500 (c) 300 (d) 250 (e) 180 (f) 100 (g) 75 µm sieve (h) receiving pan

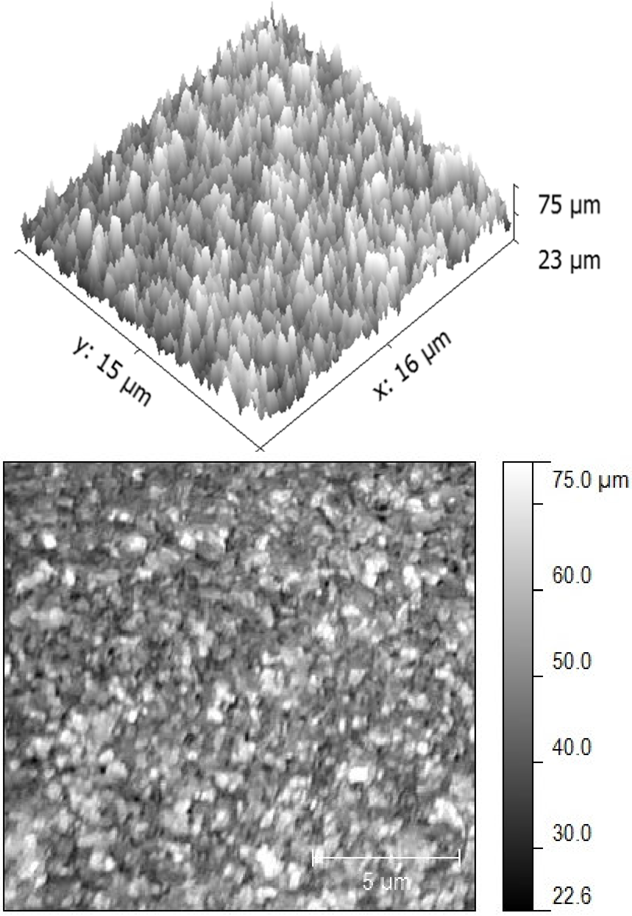

Fig. 5. Size of the Al (1050) received in the pan.

Summary and Conclusions

Milling duration up to 40 hours at 8.5 charge ratios with different diameters-ceramic balls was applied in this study. Particle size analysis revealed that the obtained particle size varied between 600 and 22µm. Hence lathe machining and ball-milling techniques proved to be an adequate and efficient process for the synthesis of Al (1050) particles using carbonised coconut shell particles as a process control agent. The produced Al (1050) particles containing 0.1% carbonised coconut shells could be used as a microfiller for polymeric composite production.

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