

Production and Characterisation of Ash Reinforced Cast Motorcycle Piston using Aluminium Alloys Scrap

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Abstract— this research work deals with the production and characterization of a motorcycle piston from locally sourced recycled Aluminium piston scraps, using stir casting method. Recycled Aluminium piston scrap was used as the metal matrix and charcoal ash contents of constant percentage was used as the reinforcement in the fabrication of the metal matrix composite (MMC). The compositions of the recycled piston scrap and charcoal ash were acquired. The tensile, hardness and wear resistance properties of the as-cast and reinforced composites were studied. The result indicated that there was increase in the hardness and wear resistance of the reinforced composite, which may be due to the hindrance in dislocation movement of the Aluminium particles as a result of the introduction of the charcoal particles. However, the ultimate tensile strength was found to have reduced slightly.

Index Terms— Aluminium, Ash, Composites, Mechanical Properties, Piston, Stir Casting, Wear

1 INTRODUCTION

GLOBAL environmental policies and regulations have prompted the search for materials that are environmentally friendly as well as decrease the rate of consumption of fossil fuel [1]. This can be achieved if the efficiency of the automobile is improved by reducing the weight of the automobile whose main components are the engine and the frame. Engine piston is an element of the crankshaft assembly, which take part in the conversion of thermal energy into mechanical work [2]. The piston is one of the most stressed components of an entire vehicle. Engine piston failures occur at various mile-ages and are due to different causes. These failures are caused by material defects and engineering and operational errors. Materials that are most commonly used for manufacturing pistons include: cast iron, alloy steel and aluminium alloys, aluminium-silicon (Al-Si) alloys and aluminium-copper (Al-Cu) alloys.

Aluminium alloys are distinguished by good formability during casting and good machinability. These alloys are characterised by their low hardness and strength indices at elevated temperatures, low wear resistance and large thermal expansion coefficient [3]. To overcome these shortcomings, these alloys are reinforced with ceramic materials to develop new composite materials.

Composites are emerging engineered materials produced from a combination of two or more materials in which tailored properties can be achieved. The term composite broadly refers to a material system which is composed of a discrete constituent (the reinforcement) distributed in a continuous phase (the matrix) and which derive its distinguishing characteristics from the constituents and from the properties of the boundaries between the different constituents [4]. Composite materials offer high strength to weight ratio, corrosion resistance, and good fatigue resistance which makes them highly competitive against conventional materials.

Recently, an extensive variety of research interest has been ongoing by attempting to introduce reinforcement materials into aluminium matrix with the aim of improving and enhancing the properties of the composite. The most frequently used reinforcement in developing pistons of combustion engines are alumina (Al_2O_3), Silicon Carbide (SiC), graphite and fly ash [5]. The addition of these hard ceramic materials into the aluminium alloy makes it possible in developing new materials with better mechanical properties than the matrix [6] [7]. Walczak *et al* [8] reported that pistons made of composites and characterized by limited specific weight make it possible to increase their fatigue strength and the resistance to thermal shocks in the piston bottom and jacket area operating in extreme temperature environment.

Some of the techniques used by researchers are casting, powder metallurgy, friction stir processing, ball milling and hot rolling. However, casting process is largely used as a result of its low cost, capability of producing large complex shapes and high production rate [9]. To be able to produce high-quality castings from composites, studies have shown that several modifications must be made to the normal melting and casting practice. The most obvious modification involves the continu-

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ous stirring of the molten composite in order to keep the reinforcement particles in suspension. The alloy should be melted at a controlled temperature and the desired quantity of reinforcement added to the molten aluminium alloy [10].

This research was motivated by the limited number of findings reported on the effect of locally sourced ash reinforced aluminium alloy metal matrix composites. Non uniformity in the particle size and composition of charcoal ash is another major problem in ash reinforced aluminium MMCs. Therefore, the aim of this paper is to study the effect of a locally sourced charcoal ash addition on the mechanical and wear properties of a recycled scrap Aluminium alloy.

2 MATERIAL AND METHODS

2.1 Material

The raw materials used in the research work include recycled Aluminium motorcycle piston and ash powder, both sourced locally in Kaduna, Nigeria. The chemical composition of the matrix materials and the reinforcement was investigated at Solid Mineral Research Centre (Step-B), Kaduna Polytechnic, and is shown in the tables 1 and 2 below.

Table 1: Chemical Composition of Aluminium scrap

% Al	% Si	% Fe	% Mn	% Mg	% Cr	% Zn	% Cu	% Ti	Total
85.20	13.0	0.6	0.5	0.1	0.2	0.1	0.1	0.2	100

Table 2: Chemical composition of ash particles obtained using XRF

Compound	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	TiO ₂	K ₂ O	Na ₂ O
Weight %	40.3	24.5	26.2	1.2	2.2	0.6	1.7	1.4

2.2 Method

2.2.1 Production of Piston Core

Pure silica sand was used in the production of the piston core. A binder (sodium silicate) and sugar were added and mixed thoroughly with the silica sand. The addition of sugar is to improve the collapsibility and ease of knockout of the core. A split core box was rammed full with the mixed core sand; it is then baked to reduce the moisture content of the mixture as well as making it more compact. This method was adopted by Ozioko (2012) [11]. Plate 1 below shows the baked mixed core sand.



Plate 1: Baked mixed Core sand

2.2.2 Production of Casting

This method was adopted by Datau et al (2017) [12]. Recycled motorcycle engine Aluminium piston, free from dust and contamination, were charged in a crucible and kept in a charcoal furnace. A blower was used to superheat the temperature. At the start of melting of recycled aluminium, the temperature of the furnace was raised to about 660°C and at this temperature the pure aluminium was melted. After a time interval of 9 minutes, the aluminium melt was stirred thoroughly to ensure homogeneity. With steady heating, the furnace temperature was raised to 720°C and the melt was held at this temperature for few minutes.

The composite materials were prepared by dispersing the reinforcing ash particles in the recycled piston scrap melt using stir-casting technique. The steps involved in preparing the composite were: stirring the melt using a mechanical stirrer, dispersing the preheated ash particles of size less than 40µm in the vortex of the melt with stirring speed of 600 rpm for 3 minutes and pouring the melt in the sand mould. The mould, having predefined cavity of required piston dimensions was allowed to cool to room temperature. The reinforced cast piston was then removed from the sand mould and was machined to the required piston dimension. The same procedures were followed for preparing separate composite material containing 0% weight ash in recycled piston melt. The reinforced and unreinforced cast pistons are shown in Plate 2 below.

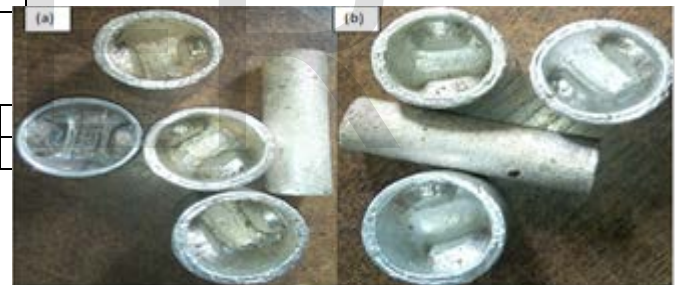


Plate 2: (a) Ash reinforced Piston (b) Unreinforced Piston

2.2.3 Machining of Piston

The reinforced and unreinforced cast pistons were fettled, placed in the lathe and machined to standard specifications of Jincheng motorcycle piston. The pistons after machining were subjected to surface finish and dimensional accuracy by touch, visual inspection, and use of Vernier caliper. The machining process is shown in plate 3 below.



Plate 3: Machining of Cast Piston

2.2.4 Characterization of Composite

Two (2) samples each of reinforced and unreinforced composites were made for tensile, hardness and wear resistance tests. The samples were in accordance with ASTM standard method of testing of materials. For the tensile test, the grip end of the test samples were attached to the grip holder of the tensile machine (i.e. Mosanto Tensometer) and a gradual application of tensile load through a wheel were applied on the specimen until fracture.

Hardness test was carried out to measure the capacity or ability of the material to withstand or resist indentation, using the Avery Visual Hardness Testing Machine. An indenter of 2mm (0.002m) was firmly fixed in the machine's chuck and hence, locked via the lock knob. The test specimen was then securely placed on the anvil (work table), in an approximate centre to the indenter. The test specimen was elevated, such that it is in contact with the indenter. Hence, the test specimen was put under preliminary (minor) load without shock, by moving the hand wheel. Thus, the test specimen was put under major load of 120kg via the loading lever. The pointer was then observed, until it comes to rest. After, a period of approximately 15sec, the major load was unloaded. The test specimen was disengaged and observed under the microscope. The schematic diagram of the specimen for tensile and hardness tests are shown in the figure 1 (a) and (b) below.

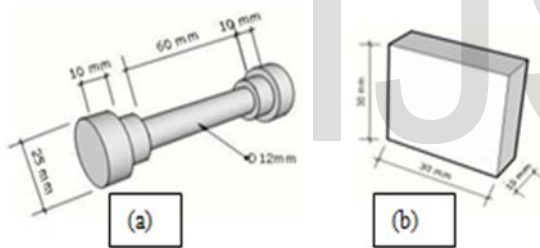


Figure 1: (a) and (b): schematic diagram of the tensile (a) and hardness (b) specimens [12]

2.2.5 Tribological Testing of Composites

In this test, the wear test specimen in the shape of a cylinder was pressed under load onto a rotating disc made of hardened steel. The distance of the pin from the centre of the disc and the rotating speed was controlled to obtain a constant sliding velocity. The constant sliding distance was achieved by calculating the number of disc revolutions and wear. Tests were carried out for constant load i.e., 453g for the cast materials. The sliding velocity and the sliding distance were fixed at 0.15m/s and 9 and 18 metres for a sliding time of 60 and 120 seconds.



Plate 4: Stationary pin and rotating disc

3 RESULTS AND DISCUSSIONS

3.1 Chemical Composition Analysis

The chemical composition of the reinforced and unreinforced composites were conducted and presented in table below. This is done in order to investigate as well as ascertain if there was substantial variation and possible reasons.

Table 3: Chemical composition analysis of reinforced and unreinforced cast

Material	Chemical composition (%)								
	Fe	Cu	Si	Zn	Mg	Mn	Cr	Ti	Al
Unreinforced	0.6	0.1	9.5	0.1	0.5	0.1	0.2	0.2	Ba
Reinforced	2.4	0.8	14.3	0.1	0.2	0.6	Ni	0.1	Ba

From the result of the chemical composition analysis, it can be seen that there is decrease in the percentage amount of magnesium. This could be due to the excessive melting temperature and volatility of magnesium in molten form as well as reaction between the metal alloy and the preheated ash particles. Additionally, it can be seen that the percentage amount of silicon and iron has greatly increased. This could be due to the fact that the content of the elements in the ash reinforcement is high.

3.2 Mechanical Properties Test Result

The results obtained from the tensile and hardness tests are presented in Table 4 below. The table gives the tensile strength and hardness values for reinforced and unreinforced cast samples.

Table 4: Result of Tensile and hardness

Materials	Tensile (N/mm ²)	Hardness (BHN)
Unreinforced	112	60
Ash Reinforced	108	81

From the result, it can be seen that the hardness value of the reinforced composites is higher than that of the unreinforced composite. The increase in hardness could be explained by diffusion assisted mechanism, and also by hindrance of dislocation movement by reinforcing atoms, i.e. foreign particle of

second phase. The result of the tensile test shows that there is a slight decrease in the tensile strength after reinforcement.

3.3 Tribological Test Result

From the result obtained, it was found out that wear rate of the unreinforced casting is higher than that of the reinforced one. The lower wear rates in composites with charcoal ash particles were attributed to good interfacial bonding in the composites. This means that the reinforcement using charcoal ash particles protected the Aluminium alloy matrix effectively when subjected to load

Table 5: wear test result

Material	Load (g)	Velocity (m/s)	Sliding distance (m)	Time (s)	Wear loss (gram)
Unreinforced	453	0.15	9	60	0.38
Reinforced	453	0.15	9	60	0.29

4 CONCLUSION

From the result of the research, the following conclusions were drawn:

- i. Charcoal ash particles are successfully used to fabricate the aluminium matrix composite via stir casting technique.
- ii. Reinforcing aluminium piston scrap with charcoal ash enhances the mechanical properties. The hardness value of the reinforced composites was found to be higher than that of the unreinforced cast whereas there was slight decrease in the ultimate tensile strength of the composite.
- iii. The wear resistance of the charcoal ash reinforced composite was found to be better. This may be occasioned by the inhibition of dislocation movement of the particles due to presence of reinforcing materials.

5 RECOMMENDATION

At the end of the research, the following recommendations are made:

1. The percentage and size of the charcoal reinforcement should be varied, to enable researchers properly understand and find the best percentage at which the effect of charcoal ash on the mechanical properties of recycled aluminium piston can be obtained.
2. Microstructural analysis of the unreinforced and reinforced composites should be done to fully understand the microstructural changes that occur after reinforcement.

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