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Analysis and Mechanical Performance of Stone Dust Reinforced Al (6063)

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Abstract:- This research technically aims at utilizing stone dust as reinforcement to check the mechanical properties of Al(6063) with different weight ratio of the reinforcement. The alloy consisting of 0, 2, 6 and 10 wt% of the reinforcements were produced using double stir casting method. Evaluation of the microstructure, percentage porosity check, measurement of density and mechanical properties of the composites produced were used to check the performance levels of the composite produced. The results obtained show that the microstructure of the composite produced shows no discrepancy as the reinforcements were evenly dispersed in the matrix. The measured density of the composites decreases with an increase in the reinforcement. Hardness value increases with an increase in the reinforcement from 38.9-60 BHN with 12%, 56% and 74% respectively of the composite produced over the unreinforced sample. UTS value for composite with 2 wt% has the highest peak value of all the composites produced and the value decreases with an increase in reinforcement for the 6 wt% and 10 wt% respectively. However, percentage elongation values of the composites drop with an increase in the reinforcement from 8% to about 25% over the unreinforced composite. Materials resistance to crack propagation (fracture toughness), the 2 wt% reinforced composite has the highest value over others that are also reinforced. It increases by 30% over the unreinforced composite. However, corresponding decrease was observed for the 6 wt% and 10 wt% reinforced composite.

Keywords:- *Aluminium Alloy, Metal Matrix Composite, Reinforcement, Stone Dusts.*

I. INTRODUCTION

Couple of years back, most developing and advanced countries on planet earth possess huge amount of waste materials such as stone dust, agro wastes materials and fly ash. The great pill up of this has resulted into disposal difficulties that are both pricey and also environmentally unfriendly. One of the ways to reduce this disposal is by making use of them for engineering purpose (Ramesh et al., 2014).

Stone dusts are mostly considered as a waste of quarry practice follow from breaking and crushing process of rocks which are abundantly rich in silicon dioxide and Al2O3, very low density (1.8-2.1 g/cm3) in comparison to other reinforcing materials like Alumina, readily useable in great quantity, and no danger caused to the environment.

Aluminium alloy has the versatile property of light weight has been make the researchers keen interest to enhancing the technology (Muthukumar et al., 2012). However, dimensional instability and low temperature properties drastically limit their uses only to temperature below 100ºC. To have a sole aim of reducing this problem, one positive ways has been by reinforcing the alloy with ceramic materials in a particulates form with the primary aim of improving on its high temperature properties and mechanical properties. Aluminium matrix composites containing fibers, whiskers(ceramics) and particles have been explored for auto parts such as piston and cylinder liner in car engines due to the highly comprehensive wear properties (Choi *et al*., 2010). However, due to high cost of these conventional reinforcing materials, investigation has been carried out in the usage of these cheap materials such as stone dust, mud and silica particulate (Alaneme *et al.*, 2016)

This research investigated the use of stone dust as a reinforcing material to check the mechanical effects of this reinforcement on Al (6063).

II. MATERIALS AND METHODS

A. Materials

Aluminium ingot was used as the matrix for the production of aluminium based composites. Stone dust having the mean particle size of 80 µm which was gotten from industrial waste was used as the reinforcements.

B. Production of Al (6063) Based Composite

Two fold steps stir casting approach observed as reported by Alaneme and Olusola (2017) were explored to makr the composites. The process began with the actual determination of the quantity of stone dust which consists of 2%, 6% and 10% respectively. Aluminium was charged into the crucible and placed inside the diesel pit furnace and heated at temperature of 670˚C until aluminium melted completely. The temperature was lowered to about 500ºC so as to add the reinforcement. it was stirred at 200rmp for 5mins to achieve homogenization. The mixture was stirred using a mechanical stirrer; The stone dust was preheated before it was added to the molten aluminium and stirred manually. Thereafter the liquid composites was deslagged and cast in the already made sand mold.

$Si \times 10^{-2}$	$Fe\times 10^{-2}$	$Cu\times 10^{-2}$	$Mn\times 10^{-2}$	$Mg\times 10^{-2}$	$Zn\times 10^{-2}$	$Ti\times 10^{-2}$	$Cr\times 10^{-2}$	$Al\times 10^{-2}$
45	22	2	3	5	2	2	3	Balance

Table 1:- Chemical Composition of Aluminum (6063) Alloy

C. Microstructural Examination

A Metallurgical Microscope(Zeiss) with tools for image analysis were used for optical microscopic check of the composites made. The specimens undergone polishing and etching before microscopic check was carried out. The specimens were lathe-cut from rods and then ground and polished. Grinding operation was executed with emery paper (80-1200) grits, while polishing operation was done using polishing cloth and paste with Al_2O_3 particles. The polished samples were viewed under microscope but etched in dil aqua regal.

D. Density Measurement and Percentage Porosity

Density checks were also considered during the course of this research to examine the outcome of stone dust weight percent ratios on the densities of the produced composites. The measured density (experimental) was also used to check how porous the composites are. This was accomplished by comparing the experimental and theoretical densities of each weight ratio of stone dust in accordance with (Alaneme, 2013)The experimental density was figured out by the division of the measured weight and its volume; while the theoretical density followed the rule of mixtures.

The relation used by (Alaneme, 2011) for the percent porosity was observed:

$$\% \, porosity = \{(\rho T - \rho EX) \div \rho T\} \times 100\% \quad (1)$$

Where;
ρT= Theoretical Density (g/cm3),
ρEX= Experimental Density (g/cm3).
(Alaneme, 2012)

E. Mechanical Properties

The hardness testing was carried out for all composite specimens. Before the test was carried out the mating surfaces of the indenter, plunger rod and test samples were cleaned by removing dirt, scratches and oil and the testing machine was calibrated using the standard block. Specimens for hardness test were cut to 10 by 10 mm diameter size and were properly grinded. A direct load of 120kgf was then applied on flat smoothly polished specimens of the composites for 10 seconds and Brinell hardness test was carried out (Brinell hardness value scale A). The test was repeated three to times and the average reading was taken. Tensile tests were carried out and evaluated on each composite made using a circular specimen form with 2.5mm radius and 30mm gauge length in accordance with ASTM 8M-91 standard at 25°C by Instron universal testing machine operated at a strain rate of 10-3/s. UTS and % elongation were assessed from the stress-strain graph obtained from the tensile test.

Circumferential notched tensile (CNT) specimen procedure was adopted to assess the K_{IC} (fracture toughness) of the composites made. Samples produced were machined to a CNT configuration, and the gauge length of 30mm, diameter of 5.5mm (D), diameter of notch of 4.5mm (d) and angle of notch of 60 degrees were noted. The specimens afterwards were subjected to tensile loading to fracture using an Instron universal testing machine. The K_{IC} was evaluated using the formular reported by Dieter (1988):

$$KIC = Pf/D^{3/2}\,[1.72(D/d) - 1.27] \quad (2)$$

Where; D and d are the diameter of the specimen and the diameter of the notched section respectively. Evaluation of the K_{IC} was determined according to (Nath and Das, 2006):

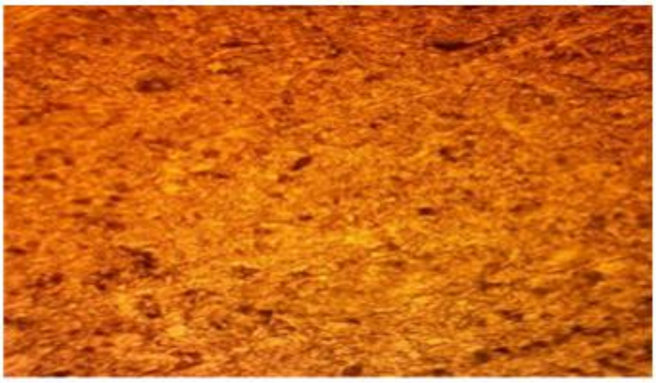
$$D \geq (KIC\,/\,\sigma y)^2 \quad (3)$$

The above relation helped with the fracture toughness evaluation.

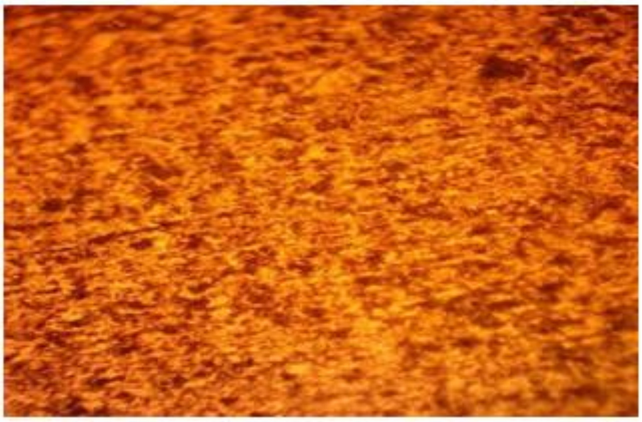
III. RESULTS AND DISCUSSIONS

A. Microstructure

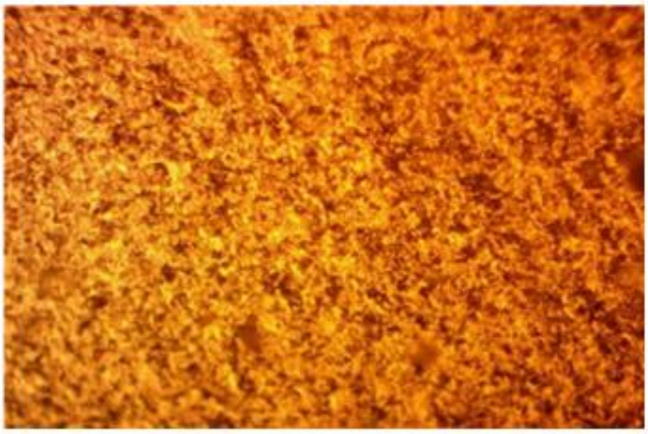
Fig. 1(a-d) shows the optical microscopy results of some selected composites reinforced with stone dusts. Figure 1a which happens to be the unreinforced composition shows a structure synonymous to a pure Al6063 from literature. The other microstructures appear with almost similar pattern showing some different variation of the reinforcements. The morphology together with the grain structure look alike with same features



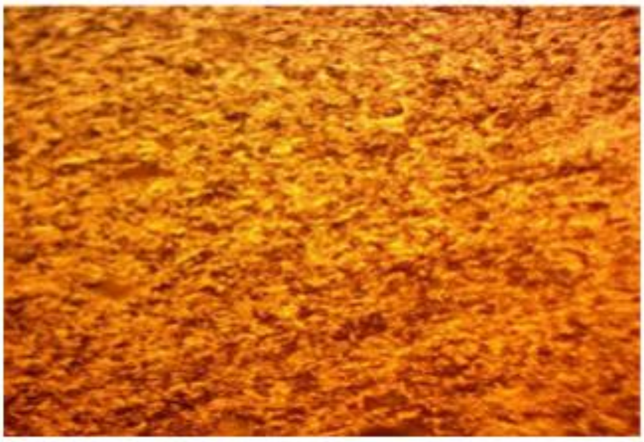
(a)



(b)



(c)



(d)

Fig 1:- Representative Microstructures (Optical Microscopy) of Al Composites. (a) Pure Aluminium of Magnification of x400 (b) 2 wt% Stone Dust Particle of x400 Magnification (c) 6 wt% Stone Dust Particle of Magnification X400 (d) 10 wt% Stone Dust Magnification x400

B. Mechanical Behavior

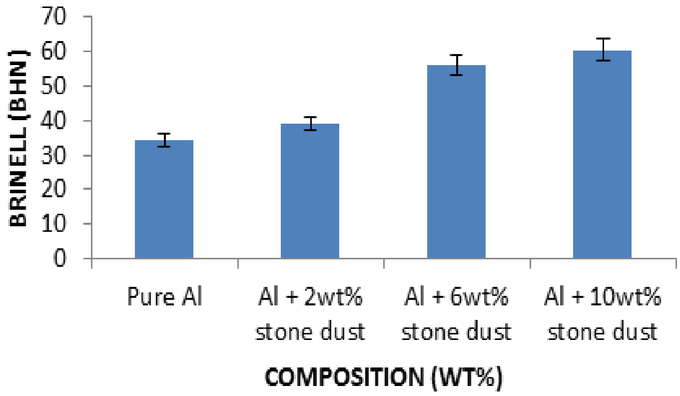


Fig 2:- Hardness of the Composite Variation Containing Varying Weight Ratio of Stone Dust

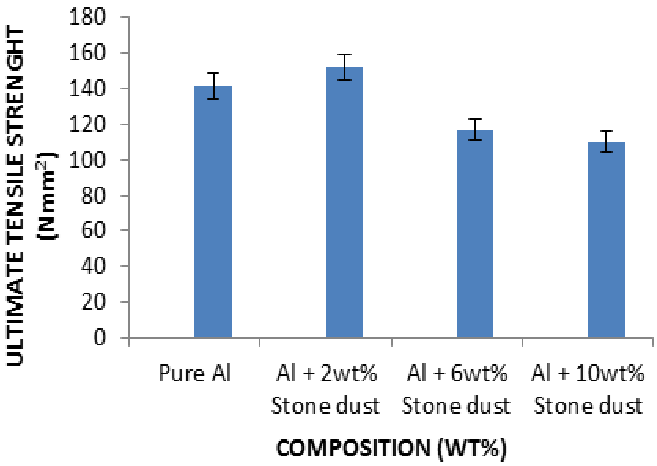


Fig 3:- Ultimate Tensile Strength Variation of the Composite Containing Varying Weight Ratio of Stone Dust

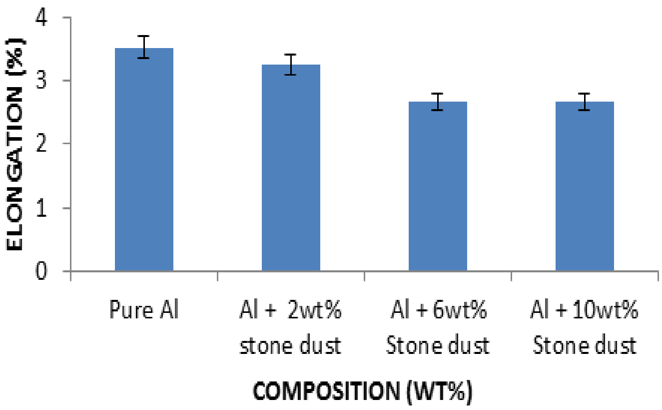


Fig 4:- Percentage Elongation Variation of the Composites Containing Varying Weight Ratio of Stone Dust

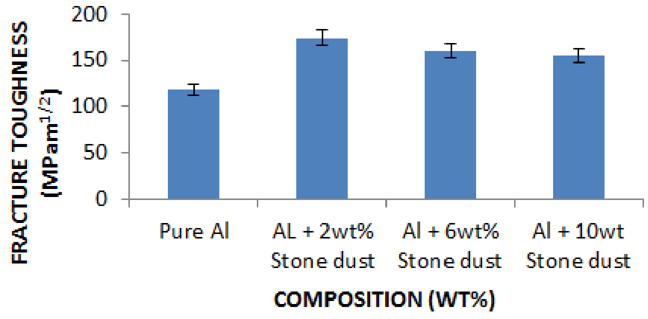


Fig 5:- Fracture Toughness Variation of the Composite Containing Varying Weight Ratio of Stone Dust

The evaluated mechanical properties of the composites produced are shown from Fig. 2-5.

Fig. 2 compares the hardness value of the composite produced with different wt. % of the reinforcement. It is observed that the hardness value increases with an increase in the reinforcement from 38.9BHN to about 60BHN at about 12%, 56% and 74% respectively of the composites produced over the unreinforced sample and this can be attributed to the higher hardness properties of the stone dust and resistance to surface plastic deformation offered by the it.

For the tensile tests results, it is observed that the composition with 2 wt% has the highest peak of all the composites produced and the value decreases with an increase in reinforcement for the 6 wt% and 10 wt% respectively. The highest peak value obtained could be as a result of the sufficiency of the reinforcement to form a stronger interface bonding thereby increasing its strengthening.

For the percentage elongation, it is clearly observed that the values of the composites drop with an increase in the reinforcement from 8% to about 25% over the unreinforced composite. This might be attributed to the brittle nature introduced into the composites system. The 2 wt% which has about 8% elongation gives an indication of sustaining more plastic strain before fracture over the 6 wt% and 10 wt% reinforced composites.

For the fracture toughness (KIC) which is also the measurement of materials resistance to crack propagation, which is presented by Fig. 5 shows clearly that the 2 wt% reinforced composite has the highest value over others that are also reinforced. It increases by 30% over the unreinforced composite. This is an indication that the sample will not likely fail by brittle mode type of failure.

IV. CONCLUSION

The microstructural analysis and mechanical effect of stone dust on Al6063 containing 2 wt%, 6 wt% and 10 wt% as reinforcement were investigated.

The results show that:

- The microstructures of the composites are similar and the reinforcements are dispersed evenly in matrix system.
- Hardness value increases with an increase in the reinforcement from 38.9-60 BHN with 12%, 56% and 74% respectively of the composite produced over the unreinforced sample.
- UTS value for composite with 2 wt% has the highest peak value of all the composites produced and the value decreases with an increase in reinforcement for the 6 wt% and 10 wt% respectively.
- Percentage elongation values of the composites drop with an increase in the reinforcement from 8% to about 25% over the unreinforced composite.
- Materials resistance to crack propagation (fracture toughness), the 2 wt% reinforced composite has the highest value over others that are also reinforced. It increases by 30% over the unreinforced composite. However, corresponding decrease was observed for the 6 wt% and 10 wt% reinforced composite.

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