Hybrid Aluminium Alloy (Aa6064) Composite Mechanical Properties Investigation

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Abstract— Hybrid composite is a composite consisting of a base (matrix) and two or more reinforcing elements embedded in it. In recent times, hybrid metal base composite gained the many researchers interest due to the improved mechanical properties they offer when compared to the conventional metal base composites. In this investigation, particulate periwinkle shell ash (PSA) and fly ash (FA) served as the reinforcing elements due to their brittle properties while the base was aluminum (Aa6064) alloy. Three composite samples were cast using liquid stirring techniques by applying different weight fractions for the reinforcing elements to determine the sample with the best mechanical properties (that is with the optimal composition). Hardness test, tensile test, impact test was carried out on the samples. From the results of the tests, composite sample 'B' produced the optimal composition with values for hardness, tensile strength and impact energy as 88 MPa, 185 N/mm2 and 6.05 J respectively at 15 % weight fraction of PSA and 15 % weight fraction of FA in the composite. Therefore, it can be concluded that mechanical properties of hybrid composite are improved when there is equal amount of reinforcing particles in the base.

Keywords— Ash, Base, Composites, Hybrid, Mechanical Properties.

I. INTRODUCTION

Hybrid composites are meant to offer better value to the materials they are being used for. Igbax et al., (2016) emphasized the need for engineering materials to have the desired properties so that failures or breakdowns of equipment are minimized. These failures/breakdowns could arise as a result of loading on the equipment. Bako et al., (2019) also emphasized on failures based on the impact of force applied on engineering materials. From past experimental works, it has been established that particulate reinforcing elements of composites are cheaper and have relatively similar characteristics to the expensive fibres /whiskers reinforcement (Clyne et al.,2000). The dominance of hybrid composites when compared to conventional composites can be attributed to many properties which includes; balanced physical, mechanical and thermal property etc. Some of the main advantages of hybrid composites are improved fatigue resistance, reduced weight, improved fracture toughness, reduced cost, reduced notch sensitivity, high impact resistance ability etc. (Chamis et al.,1977). Aluminium (Aa6064) alloy is one of the commonly used alloys in met al., base composites due to its inherent alloying elements such as magnesium and silicon. The magnesium helps to improve the bonding between the alloy and the reinforcing particles adds to the mechanical value of the composite.

Periwinkle also known as winkle can be described as a darkish, tiny eatable whelk that is round-like and with a strong covering (Sadiq et al.,2020). Improved and better mechanical properties of composite materials can be influenced by the particle geometry (Felix et al., , 2014 and Umunakwe et al.,2017). Periwinkle shell ash contains silicon, calcium, aluminium oxides as its core oxides and are contributing factor to its abrasive nature (Felix et al.,2014). Availability of fly ash and the inherent abrasive and brittle nature of the ash have made it a very useful reinforcing particle in met al., base composite in recent times. Many researchers over the years have worked on fly ash as a reinforcing particle in met al., base composite. Their works have revealed that fly ash is a better replacement for silicon carbide because it contains constituents that are ceramic. Kurmar et al., (2022) carried out a study on the characterization of aluminum base composites using particulate silicon nitride through liquid state fabrication techniques (stir casting). In their work, it was concluded that silicon nitride (Si3N4) particles were evenly distributed in the Aa6061 base and that the mode of failure of the Aa6061 and Aa6061/20wt % Si3N4 were different. Saikrupa et al., (2021) did an extensive review on reinforcing effect on aluminium met al., base composite. They concluded that stir casting method of producing met al., base composite is less expensive and common method of producing composites compared to other methods. Nwigbo et al., (2022) compared nano-composite and Aa6061 reinforced with silicon carbide and carbonized shell micro in terms of their tensile strength. They concluded that there is a noticeable decrease in ductility of the Aa6061 reinforced particulates composite as the weight fraction of the reinforcing elements increases. Umunakwe et al., (2017) assessed certain mechanical properties and micro appearance of periwinkle shell Aa6063 produced by two step techniques. They concluded that periwinkle shell ash serves as a refining element in Aa6063 grains thereby contributing to the increase in toughness and hardness of the composite. This paper seeks to investigate the effect of fly ash and periwinkle shell ash on some Aa6064 alloy mechanical properties.

II. MATERIALS, EQUIPMENT AND METHOD

2.1 Materials

The main materials used in producing the composites are aluminium (Aa6064) alloy, fly ash (FA) and periwinkle shell ash (PSA). Others are magnesium used as binder and sodium chloride used as degasser in the alloy.

2.2 Equipment

Some of the main equipment that were used to conduct this investigation are; grinder and polisher, steel stirring blade, vicker hardness tester, oven, temperature reader, impact tester , X-ray fluorescence spectrometer, tensile tester, furnace, hammer mill.

2.3 Methods

2.3.1 Processing of Periwinkle Shell Ash

Periwinkle shells were washed with clean water and dried in an oven at a temperature of 1200C for one hour to completely extract the moisture content. The dried shells were thereafter broken into small pieces with the aid of a hammer and then crushed into particles in a hammer mill. The particles were calcinated at 700°C in furnace and then sieved to produce smaller particles of the same size as shown in figure 1. Characterization using X-Ray Fluorescence (XRF) spectrometer was carried out on the processed periwinkle shell ash in order to obtain the chemical composition.

Figure 1: *Periwinkle Shell Ash*

2.3.2 Processing of Fly Ash

Figure 2 shows fly ash was obtained in a processed form using X-ray Fluorescence (XRF) spectrometer.

Figure 2: *Fly Ash*

Table 1: Samples Constituents Weight Fractions

Samples/Constituents	Aa6064 (g)	PSA (g)	FA (g)	Mg (g)	Total (g)
A (Aluminium Alloy)	1000	-	-	-	1000
B (Composites)	680	150	150	20	1000
C (Composites)	680	200	100	20	1000
D (Composites)	680	100	200	20	1000

2.3.3 Production of Test Samples

Liquid stirring technique shown in figure 3 was used in the preparing of the composite test samples. Aa6064 wires scraps were cleaned and preheating immediately carried out on them at a defined temperature of 110 degree Celsius for 40 minutes to make them completely dry. Preheating of magnesium, fly ash and periwinkle shell ash were done differently for about 45 minutes to remove any tiny surface impurities present on the particles and also moisture content. Sieving operation was carried on the preheated particles for fineness and uniformity of the particles.

The treated Aa6064 was charged into the melting chamber of the furnace where it is heated to molten state at 740 degree Celsius to become liquid and then degassed by adding sodium chloride to it. Stirring was done on the molten Aa6064 at a constant speed of 220 rpm and at a melting temperature of 740 degrees Celsius. At vortex, the FA and PSA were simultaneously added to the molten Aa6064.

The stirring speed was thereafter reduced to 95 rpm and maintained at that speed due to increased thickness of the composite mix before adding magnesium powder to lower the surface tension of the mixture, thereby enhancing bonding of the mix.

Stirring was sustained for additional 25 minutes to allow for a total and even mixing of the composite mix before being poured into the moulds to produce cast composite rods to be used for test. Samples with different weight fractions were produced as shown in Table 1.

Figure 3: *Liquid Stirring Technique*

III. RESULTS AND DISCUSSION

3.1 Results and Discussion of Chemical Compositions

3.1.1 Aluminium Alloy (Aa6064)

Table 2: Aluminium Alloy (Aa6064) Elements Weight Percentages

Elements	Mn	Si	Cr	Cu	Mg	Ti	Bi	Pb	Fe	Zn	Others	Al
Weight Percentages	0.14	0.8	0.13	0.40	1.20	0.15	0.70	0.40	0.70	0.24	0.15	94.99

Table 2 shows the presence of alloying elements such as magnesium, bismuth and silicon in the Aa6064 used as the base. Silicon contributes a larger percentage amongst other alloying elements of the alloy. The strength of the aluminium alloy is increased by magnesium silicate (Mg2Si) as a result of the reaction that occurs between the alloying elements (silicon and magnesium) in the alloy.

3.1.2 Fly Ash

Table 3 shows the various constituents contained in fly ash and their respective weight percentage.

Table 3: Fly Ash Constituents Weight Percentages

Constituents	CaO	SiO_2	K_2O	Al_2O_3	SO_3	Na_2O	Fe_2O_3	MgO	Loss of Ignition
Weight Percentage	1.51	55.15	1.69	24.76	0.16	1.51	11.29	0.26	3.67

X-ray Fluorescence spectrometer was used to determine the weight percentages of fly ash constituents and was found to contain silicon oxides, aluminium oxides and iron (III) oxide as its main constituents. The abrasive properties or ceramic nature of the oxides makes fly ash a good substitute to silicon carbide used in most met al., base composites.

3.1.3 Periwinkle Shell Ash

Table 4 shows the different constituents contained in periwinkle shell ash and their respective weight percentage.

Table 4: *Periwinkle Shell Ash Constituents Weight Percentage*

Constituents	MgO	SiO2	ZnO	Fe203	Al203	CaO	CuO	K20	Na20		MnO2	Loss of Ignition
Weight Percentages	1.25	33.2	3.21	5.1	9.2	41.03	1.03	1.42	1.38		1.01	2

X-ray fluorescence spectrometer was also used to determine the weight percentages of periwinkle shell ash. Just like the fly ash, periwinkle shell contains silicon oxides, aluminium oxides and iron (III) oxide as its main constituents besides calcium oxides with the highest weight percentage of 41.03 % making periwinkle shell ash to also have abrasive and ceramic properties.

3.2 Results and Discussion of Mechanical Properties

3.2.1 Hardness Property

Increasing the amount of PSA and FA particles in Aa6064 leads to higher resistance of the developed hybrid composites to scratch and indentation. Composite sample 'B' produced the highest hardness value of 88 MPa as shown in figure 4. The higher resistance ability of the developed hybrid to scratch and indentation is due to the presence of homogeneous ceramic phase of PSA and FA in Aa6064 hybrid composites. The evenly distribution of the reinforcing PSA and FA particles and the homogeneous mix (bond) between the Aa6064 base and the reinforcing particles are also responsible for the hardness of the hybrid composites.

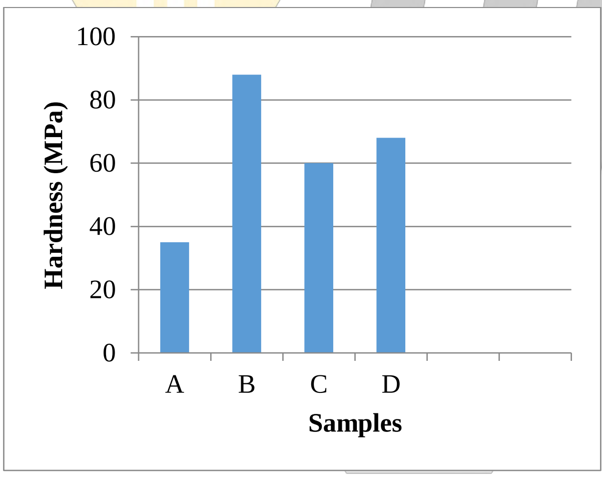

Figure 4: *Chart of Hardness against Samples*

3.2.2 Tensile Property

In figure 5, composite sample 'B' has the highest tensile strength of 194.5 N/mm2. This is because it has equal amount of PSA and FA in it. The equal amount of the reinforcing particles produced a larger fraction of ceramic oxides in the hybrid composite thereby increasing the strength of the composite. Also, either or both solid solution strengthening as a result of the atoms of the alloying elements coming together or/and the finer grain size of the reinforcing elements (PSA and FA) is/are responsible for increased hardness of the hybrid composites.

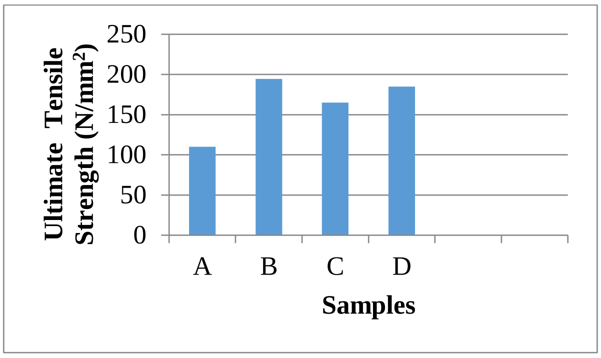

Figure 5: *Chart of Ultimate Tensile Strength against Samples*

3.2.3 Impact Property

Addition of PSA and FA reinforcing particles in the Aa6064 has negative effect on hybrid composites such that it leads to decrease in the impact energy as shown in figure 6. Composite sample 'B' has the lowest impact energy of 6.05 J while composite sample 'C' has the highest impact energy of 12.1 J. The decrease in impact energy of the composites is caused by the presence of the reinforcing PSA and FA metallic oxides containing particles that altered the ductile phase of Aa6064 alloy whereas the different values of impact energy of the developed hybrid composites is as a result of difference in the amount of the metallic /ceramic oxides in the reinforcing elements (PSA and FA).

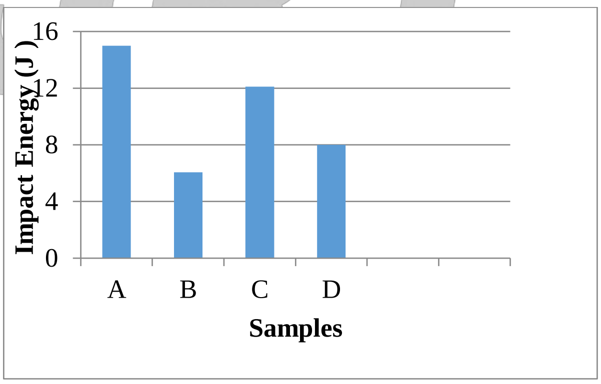

Figure 6: *Chart of Impact Energy against Samples*

IV. CONCLUSION

Hybrid addition to material has significant advantages and produces mechanical properties significant to aluminum alloy. Mechanical properties such as impact, hardness and tensile strength of the developed hybrid composites are affected by the reinforcing PSA and FA particles due the presence of met al., lic oxides in them. Increase in PSA and FA in the Aa6064 leads to higher value of tensile strength and hardness of the developed hybrid composite while the impact energy decreases. The bonding of the reinforcing particles of PSA and FA with Aa6064 is greatly influenced by the addition of magnesium powder in Aa6064.

The absence of defects such as porosity in the developed composites shows that sodium chloride is a good degasser for Aa6064.

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