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The Effect of Palm Kernel Shells Particles Reinforcement on Tensile and Compressive Properties of Aluminum Matrix Composite

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Abstract-In the quest to satisfy the ever-increasing demand for tailor-made, efficient, and cost-effective materials, there has been continuous research and development to design materials with optimum performance at different conditions, and such properties to cope with the different working conditions cannot be obtained from a single material, hence the need for composites, which combine two or more materials with each retaining its individual properties. Aluminum has found applications in multiple sectors due to its lightweight, corrosion resistance, and cheapness, among other properties; however, it exhibits low mechanical properties such as tensile strength, ductility, impact strength and so on. Aluminum from waste sources is recycled in this study by stir casting with varying percentages of 5%, 10%, and 15% by weight of 75um Palm Kernel Shell (PKS) particle size as reinforcements. The tensile and compressive strengths were measured. The results show that the reinforcement increased aluminum's compressive and tensile strengths, with the peak values for both tensile and compressive properties observed at 5% PKS.

Keywords: Metal matrix composite, palm kernel shells, aluminum matrix composite, compressive strength, tensile strength.

1. Introduction

Composites are comprised of two phases; the continuous phase (matrix) and the discontinuous phase (reinforcement). The matrix binds the reinforcement giving it a desired shape. Both the matrix and the reinforcement are very fundamental in determining the overall strength of the composite. Matrix materials used for composites include polymer matrixes (PMs), metal matrixes (MMs), and ceramic matrixes (CMs) [1]. Matrix plays the following functions: support for the dispersed phase (discontinuous phase or reinforcement), support in load bearing, provide structural stability, enhance the bonding of reinforcement, protect the composite against the surrounding environment, resist the development and expansion of cracks, deform elastically when loaded, and so on. Factors such as ductility, strength at high temperatures, density, the type of reinforcement, and the manufacturing processes are vital in selecting matrixes for applications [2].

Metal Matrix Composites (MMCs) utilizes base metals such as Aluminum (Al), Copper (Cu), Iron (Fe), Magnesium (Mg), Nickel (Ni), Titanium (Ti) and Cobalt (Co)[1,3] as matrix and other metals and or ceramics and organic compounds as the reinforcement. The reinforcements are used to improve properties such as mechanical properties [4], physical properties, magnetic properties, and electrical properties.

Aluminum as the most abundant metal on earth is a widely used metal matrix material in different industries, either alone or as alloys, oxides, and sulfates. Metal Matrix Composite that has aluminum as the base metal is referred to as Aluminum Matrix Composites (AMCs). Aluminum is widely used because of its remarkably low density, high availability, formability, recyclability, high resistance to corrosion, low cost, and so on. Its matrix products have been extensively used in the automobile, aerospace, packaging, sports and recreation, building and construction, electrical transmission, marine, and rail transport [1,3,5]. Ceramics-based reinforcements which can be carbides, oxides, or borides such as Al2O3, TiB2, TiO2, SiC, TiC, B4C, and so on are normally used to improve the properties of aluminum in AMCs [6]. Fly ash has also been reported to have gained popularity in recent times due to its low cost and availability as waste in some industries [4,7].

Also, agro-wastes such as rice husk, bamboo leaves, coconut shells, and palm kernel shells as well as animal wastes such as egg shells and animal bones have been investigated and used to improve the properties of AMCs [8].

Palm Kernel Shells (PKS) or Oil Palm Kernel Shells (OPKS) are obtained as a waste product after the production of palm oil. Nigeria is known to be the largest producer of palm oil [9], and invariably, produces the highest amount of PKS. PKS has been utilized for reinforcement in concrete and other composites as fuel in the production of cement and water treatment. It is common in some African countries, also in Malaysia, Indonesia, and all other palm oil-producing countries [10]. PKS is rich in carbon; it also contains silicon, aluminum, iron, calcium, potassium, and oxygen. As such, it has been a good candidate for reinforcement in composites and for other purposes such as activated charcoal, water treatment, and energy generation [11]. The elemental composition of PKS is shown in Table 1 below.

Table 1. Elemental Composition of PKS particles examined through Energy Dispersive X-ray (EDX)

Element (%)	0 min (1mm)	0 min (100um)
C	64	61.7
O	34.1	37.4
Si	0.9	0.4
Al	0.2	0.1
Fe	0.2	0.2
Ca	0.1	0.3
K	0.1	-

Source:[11]

Palm Kernel Shells particles have been researched by some researchers to establish their suitability as a composite material. Edoziuno et al. [12] investigated the physical, chemical and morphology of palm kernel shell particles as reinforcement for aluminum matrix. The result indicated through the structural assessment that there was a presence of elements and oxides that could improve the structural, physical, and mechanical properties of the base alloy. Agunsoye et al. [13] reported the Mechanical Properties of Kernel Shell Reinforced Al-Mg-Mn Composites, the mechanical properties such as tensile strength, hardness, and impact energy were shown to have improved by significant amounts.

Palm Kernel Shells in Nigeria despite their potential are often thrown away as waste and have not been adequately utilized in the country. PKS has so much potential as a reinforcement material that when explored can reduce the cost of reinforcement materials as well as minimize its wastefulness in the country.

In this research article, the objective is to study the compressive and tensile properties of waste Aluminum reinforced with PKS particles in variable percentages by weight of 5%, 10%, and 15%.

2. Materials and Methods

2.1. Materials

Dried Palm Kernel Shells (PKS) were collected in Benue State. The Aluminum top-cylinder engine of an automobile was purchased from waste dealers in Bauchi, washed, sun-dried, and stored for casting.

2.2. Methods

The dried PKS were sorted to remove impurities after which it was ground; thereafter it was sieved to 75um particle size and kept for onward usage.

The Aluminum obtained was heated and melted in a cast iron pot inserted in the improvised furnace shown in Figure 1 below and was treated with Potassium Chloride (KCl) flux and the impurities were scooped. The control sample was cast in the laterite soil moulds prepared as shown in Figure 2 below. The other portion of the molten Aluminum was allowed to cool and solidify.

Fig. 1. Furnace used for melting Aluminum

Fig. 2. Making of moulds from laterite soil

The 448g of Aluminum was weighed using a weighing balance and was put into the furnace and heated in the closed furnace 5% (22.4g) of PKS was added, stirred, and poured into the moulds and allowed to cool in the moulds in the air for 24 hours. The same procedure was repeated for other samples and the various composition of each sample is shown in Table 2 below.

2.2.1. Compressive Test

The compressive strength test was carried out using an ELE 2000KN capacity automated compressive testing machine as shown in Figure 3 below and the readings were read on at the point of failure. The sample sizes were 400 x 400 x 400mm. The initial and the final sizes were measured with a vernier caliper and recorded.

Fig. 3. Compressive testing machine

The compressive strength of the samples was calculated using the Eq. (1) below.

$$Compressive\ Strength = \frac{Load\ at\ Failure}{cross\ sectional\ area} \times 100 \quad (1)$$

The percentage reduction in height was calculated using the Eq. (2) below.

$$\%\ reduction\ in\ height = \frac{Initial\ height - final\ height}{Initial\ height} \times 100 \qquad (2)$$

2.2.2. Tensile Test

The tensile strength test was carried out on the Universal Testing Machine (UTM) shown in Figure 4 below. The initial and final lengths of the samples were measured with the vernier caliper and recorded to ascertain the percentage of elongation. Also, the diameter was measured and inputted into the machine through the CL-03 control. The surface area and the tensile strength were calculated automatically by the machine and were read off the screen and recorded.

(a)

(b)

Fig. 4. (a) UTM (b) UTM CL-03 Control and screen

The percentage elongation was calculated using the Eq. (3) below.

$$\%\ elongation = \frac{Final\ length - Initial\ length}{Initial\ length} \times 100 \qquad (3)$$

Table 2. Samples Composition

S/No	Al (Kg)	PKS particles (Kg)	PKS (%)
1	0.440	-	-
2	0.448	0.02240	5
3	0.423	0.04230	10
4	0.449	0.06735	15

The stir casting was carried out using the composition in Table 2 above.

(a)

(b)

Fig. 5. (a) Samples produced for tensile strength (b) samples for compressive strength

3. Results and Discussion

Table 3 below shows the results of the compressive strength test while Table 4 below shows the tensile strength test results. Also, the graphical representation for tensile and compressive strengths is shown in Figure 6 and Figure 7 respectively.

Table 3. Results of Compressive Strength Test

Samples	Com-pressive Strength (N/mm^2)	Initial Height (mm)	Final Height (mm)	Reduction in Height (mm)	% Reduction (%)	Breadth (mm)	Surface Area (mm^2)
0% PKS	281.25	40	36	4	10	40	1600
5% PKS	311.25	40	38	2	5	40	1600
10%PKS	256.25	40	37	3	7.5	40	1600
15%PKS	119.38	40	36	4	10	40	1600

Table 4: Tensile Strength Test Results

Samples	Tensile Strength (N/mm^2)	Initial Length (mm)	Final length (mm)	Diameter (mm)	% Elongation (%)	Surface Area (mm^2)
0% PKS	417.36	265	270.0	20	1.89	314.16
5% PKS	435.58	265	267.0	20	0.75	314.16
10%PKS	433.19	265	266.0	20	0.38	314.16
15%PKS	419.30	265	268.5	20	1.32	314.16

The results presented in Table 3 show the compressive Strengths of all the samples. The result shows that, at 5%PKS the compressive strength of the aluminum composite improves significantly as also noticed in the low percentage reduction of height. However, the compressive strength decreases as the percentage of PKS particles increases and has its lowest value (lower than the control sample) at 15%PKS. This shows that the compressive strength of the Aluminum composite is optimum at 5% PKS.

Tables 4 and Figure 6 show the tabulated values of the tensile Strength tests conducted using the Universal Testing Machine. The addition of 5%PKS reinforcement increased the tensile strength of the composite by 4.36%. There is a decline in the tensile strength as the PKS particles increase, although even as the PKS particles increase from 10% to 15%, they exhibit a tensile strength that is higher than the control sample.

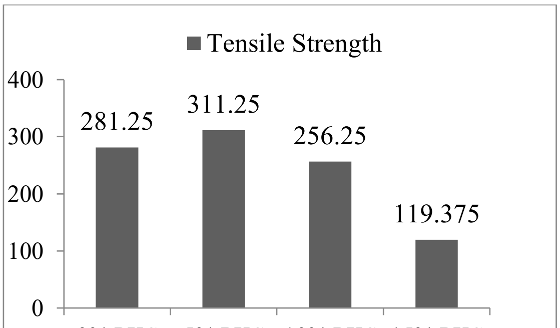

Fig. 6. Tensile strength

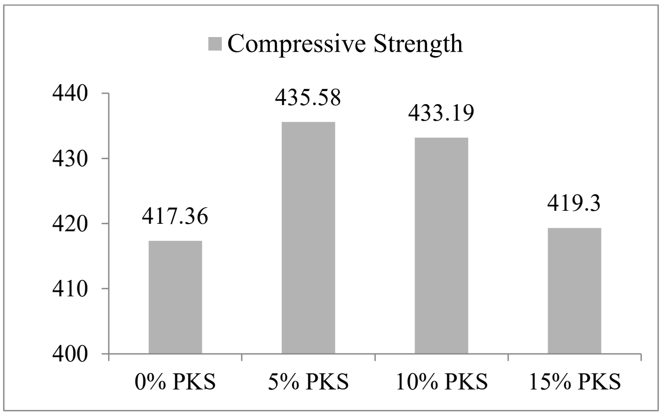

Fig. 7: Compressive strength

4. Conclusion

The effect of palm kernel shell (PKS) particles on the compressive and tensile properties of aluminum composites was investigated in this study. Composite samples with varying concentrations of PKS particles (5%, 10%, and 15%) were produced using stir casting. The results showed that the composite with 5% PKS particles exhibited the best compressive and tensile strengths. Although the other composites also showed higher tensile strengths than the control sample, the strength gains were not as significant as with the 5% PKS composite.

Overall, the results of this study suggest that PKS particles can be used as a cost-effective and sustainable alternative to other expensive particulate matter, such as carbon fibers and silicon carbide, as reinforcement for aluminum composites in engineering applications.

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