Effect of Coconut Shell Charcoal and Cow Bone Ash on the Tensile Strength and Melting Temperature of Aluminum Based Composite

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ABSTRACT

This study investigated the effect of coconut shell charcoal and cow bone ash reinforcements in composite formulation with aluminum metal matrix. Design of experiment was done using D-Optimal Mixture Design. The composite was prepared based on the different percentage by ratio of coconut shell charcoal, cow bone ash, and aluminum matrix as obtained from the design expert system. Stir casting method was used for the casting process. Tensile test was carried out on each of the 16 produced specimens and the control specimen (i.e., sample without reinforcement particles). The melting temperatures and tensile strength of the reinforced and control specimens were experimentally measured. The results obtained showed that the presence of coconut shell charcoal and cow bone ash particles in the aluminum matrix increased the tensile strength and melting temperature of the aluminum by 47.21% and 10.71%, respectively.

(Keywords: aluminum metal matrix, Al, composite, coconut shell, cow bone, reinforcement, stir casting)

INTRODUCTION

Today, the manufacture of automobiles and other sophisticated machines require design and construction materials with good mechanical and physical properties such as tensile strength, hardness, high melting point, density, etc. There is no single engineering material that has all of these mechanical properties naturally. Therefore, the understanding of new technologies in the development of new engineering materials that have good mechanical and physical properties which can be used for the production of machines and engines, such as the internal combustion engine parts cannot be overlooked. The proper joining of dissimilar materials in the right proportion is called composite engineering.

Metal Matrix Composites (MMCs) usually have less density and higher specific properties such as strength and stiffness. These composite materials are typically the combination of two or more similar or dissimilar materials, exhibiting properties that are otherwise difficult to obtain from a single material.

Research has shown that the compressive strength and tensile strength of cement can be greatly increased when about 5% bone powder are added to it (Kotb, *et al*., 2010). The tensile strength of an epoxy matrix has been found to increase when cow bone and groundnut shell particles are used as reinforcements in the composite (Agunsoye, *et al*., 2012). The tensile strength and the melting temperature of a pure aluminum metal were great increased when pure aluminum was reinforced with Palm Kernel shell and periwinkle shell (Ibhadode and Ebhojiaye, 2018).

Coconut shell ash and silicon carbide also greatly increased the tensile strength of aluminum based composed. Coconut shell is an important filler for the development of a new composites as a result of its inherent properties such as high strength and high modulus (Surappa, 2003). Coconut shell reinforced composites showed 80% better elongation at break and 20% better Charpy impact strength than soft wood composites (Andrzej, *et al*. 2010). In this study, composite material that comprises coconut shell charcoal (CSC) and cow bone ash (CBA) as reinforcements and pure aluminum ingot as the matrix element was developed.

MATERIALS AND METHOD

The reinforcement agents used in this research are coconut shell and cow bone while the matrix element is aluminum scrap. These were properly formulated to develop a composite material. The wettability of the composite was increased using pure magnesium [6]. Some equipment used in this study include, tensile test machine, electric furnace, scanning electron microscope and crucible furnace.

Coconut Shell

Coconut shell is an agro-waste that is predominantly generated in coconut candy production industry or coconut oil production facilities. The coconut shell used in this research was sun dried and heated in an electric furnace at a temperature of 700^0C for about 3 hrs. The shell was burnt to charcoal after being heating. The coconut shell charcoals were grinded into smaller particles and passed through a 212μm sieve.

Cow Bone

Cow bow wastes usually litter environments where abattoirs are located. Temitope, *et al*., (2015) [7] studied the "Effect of Cow Bone Ash Particle Size Distribution on the Mechanical Properties of Cow Bone Ash-Reinforced Polyester Composite". Their results showed that the use of cow bone ash particles of 75,106, and 300 µm led to the enhancement of the mechanical properties of polyester matrix. The cow bones used in this study were sun dried for 4 hrs to reduce the moisture content and heated in an electric furnace at a temperature 700^0C for 3 hrs. The bones were crushed to smaller particles and passed through a 425μm sieve.

Aluminum Scraps

The scraps were melted in a local furnace to remove some of the impurities present in it as shown in Figure 1.

DESIGN OF EXPERIMENT (DOE)

A three variable mixture design was used to design the experimental plan for this study using D-Optimal Mixture Design. The coded and actual levels of the factors are shown in Table 1.

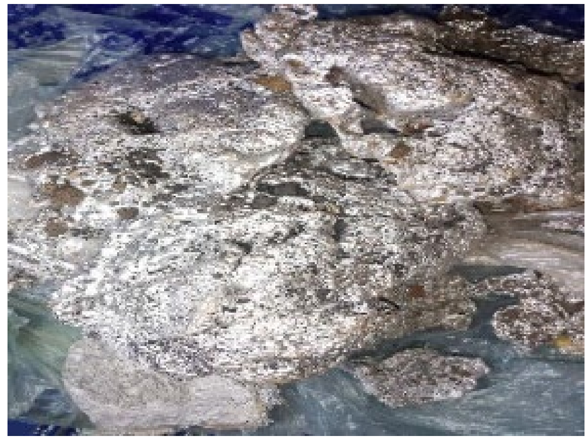

Figure 1: Aluminum Metal Obtained from Aluminum Scraps.

Table 1: Coded and Actual Levels of the Factors (Oghoghorie, *et al*., 2022)

Factors	Unit	Symbols	Variable levels	
			Low level	High level
Aluminum scrap	%	X_1	69	98
Coconut shell charcoal	%	X_2	1	20
Cow bone ash	%	X_3	1	20

The stir casting technique and sand molds were used to prepare the composite. Sixteen (16) samples of the different mix ratios as obtained from the DOE were produced and a seventeenth (17^{th}) sample which is the experimental control sample was also produced. Tensile strength and melting temperature tests were done on all the samples produced.

Table 2: Experimental Design Matrix.

Run	Actual values of factors		
	Aluminum ingot (%)	Coconut shell charcoal (%)	Cow bone ash (%)
1	69	11	20
2	79	1	20
3	79	20	1
4	90	1	9
5	79	1	20
6	69	11	20
7	85	1	14
8	69	19	12
9	98	1	1
10	84	14	1
11	69	19	12
12	76	14	10
13	79	20	1
14	98	1	1
15	90	9	1
16	83	9	8

Tensile Test Strength Test

Tensile strength is the ratio of the maximum load in a tension test to the original cross-sectional area of the test bar (Ebhojiaye, R.S.).

Figure 2 shows the developed specimens for tensile strength test. Mathematically:

$$Tensile\ Strength = \frac{Maximum\ Load}{Original\ Cross-Sectional\ Area} \quad \textbf{(1)}$$

$$Cross - Sectional\ Area = \frac{\pi d^2}{4} \quad \textbf{(2)}$$

where, d = diameter.

Melting Temperature

Melting temperature is the temperature at which a solid change to liquid under normal atmospheric pressure. In this study, the melting point for each sample was determined. This was done by subjecting the sample to heat in an electric furnace. The temperature and the melting time were recorded. The average heating rate was determined as 0.0847$^oCS^{-1}$ from the readings obtained from the different temperature range.

Figure 2: Produced Specimens for Tensile Strength Test.

RESULTS AND DISCUSSION

Tensile Strength Results

The tensile strenght results obtained for the 16 experimental samples and the control sample are shown in Figure 3. The experimental procedure was replicated thrice for each of the specimen composition and the average value were determined for each and recorded. The same was done for the control specimen. From the results obtained, it was observed that specimen with 76%. wt aluminum, 14%. wt coconut shell, and 10%. wt cow bone had the highest value of

205.35 MPa, followed by specimen with 90%. wt aluminum, 1%. wt coconut shell, and 9%. wt cow bone having a value of 185.36 MPa.

The control specimen had the least value of 139.49 MPa. This showed that the reinforcements (i.e., coconut shell charcoal and cow bone ash) increased the tensile strength of aluminum by about 47.21%. Figure 3 shows the graphical representation of the tensile strength obtained for the produced composites.

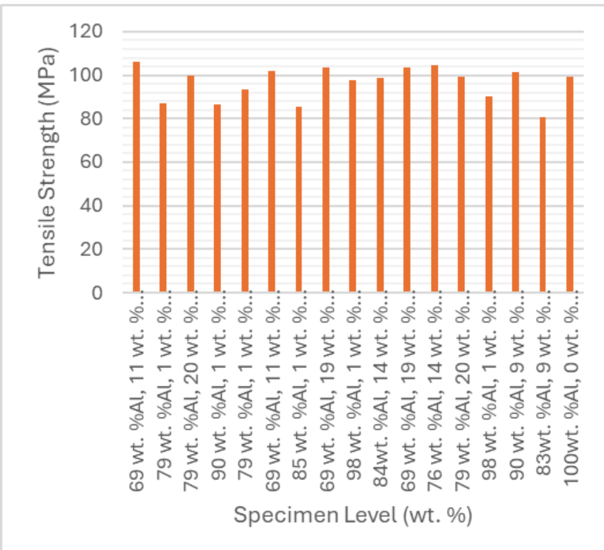

Figure 3: Tensile Strength Results of the Produced Composite.

<u>Melting Temperature Result</u>

The result of the melting temperature obtained for the 16 experimental samples and the control sample are shown in Figure 4.

From Figure 4, specimen with 98%. wt aluminum, 1% wt coconut shell, and 1%. wt cow bone has the highest melting point of 620^{0}C and the control specimen had the lowest melting point of 560^{0}C. This shows that the reinforcements increased the melting point of the composite material by about 10.71%.

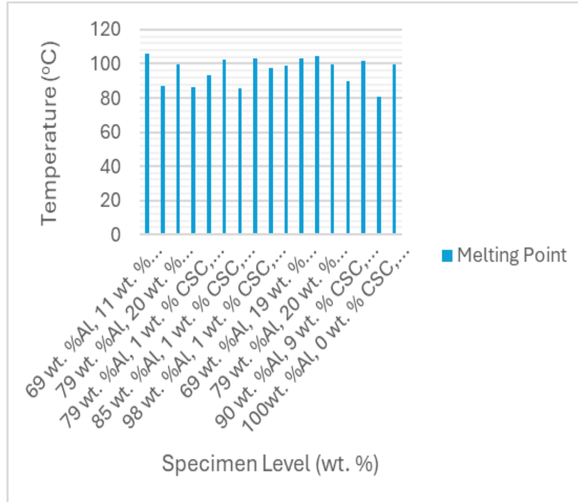

Figure 4: Melting Temperatures Obtained for the Produced Composite.

CONCLUSION

From the study, it was observed that the presence of coconut shell charcoal and cow bone ash particles within the aluminum matrix in the right proportion significantly increased the tensile strength and melting temperature of aluminum by about 47.21% and 10.71%, respectively.

REFERENCES

1. Kotb, M., M. Assas, and H. Abd-Elrahman. 2010. “Effect of Grounded Bone Powder Addition on the Mechanical Properties of Cement Mortar”. *Transactions on Ecology and the Environment*. 138. ISSN 1743-3541, doi:10.2495/DN100181.

2. Agunsoye, J.O., T.S. Isaac, and S.O. Samuel. 2012. “Study of Mechanical Behaviour of Coconut Shell Reinforced Polymer Matrix Composite”. *Journal of Minerals and Materials Characterization and Engineering*. 11(8): 774-779.

3. Ibhadode, A.O.A. and R.S. Ebhojiaye. 2018. “A New Lightweight Material for Possible Engine Parts Manufacture”. *The Future of Internal Combustion Engines, Intech Open*. 1-19. DOI:http://dx.doi.org/10.5772/intechopen.82268.

4. Surappa, M.K. 2003. “Aluminium Matrix Composites: Challenges and Opportunities”. *Sadhana*. 28 (1–2): 319–334.

5. Bledzki, A.K., A. Al-Mamun and J. Volk. 2010. “Barley Husk and Coconut Shell Reinforced Polypropylene Composites: The Effect of Fiber Physical, Chemical and Surface Properties”. *Composites Science and Technology*. 70(5): 840-846.

6. Oghoghorie, O., R.S. Ebhojiaye, and P.E. Amiolemhen. 2022. “Assessment of The Wear Resistance and the Density Reduction ff Aluminium When Reinforced with Coconut Shell Charcoal and Cow Bone Ash”. *World Journal of Engineering Research and Technology WJERT*. 8(4): 27-40.

7. Adewole, T. and I. Oladele. 2015. “Effect of Cow Bone Ash Particle Size Distribution on the Mechanical Properties of Cow Bone Ash-Reinforced Polyester Composites”. *Chemistry and Materials Research*, ISSN 2224- 3224 (Print) ISSN 2225-0956 (Online). 7(3).

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