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Reinforcement of Cast Iron with the Ashes of Animal Bone for the Production of Engineering Components

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Abstract:

The durability of engineering components is the main focus and concern of a maintenance engineer. Therefore, the study of reinforcing cast iron (CI) with the ashes of animal bones to enhance the production of engineering components is innovative in the engineering industry. Thus, investigating the potentials of cow bone ash used as composite materials to improve the mechanical properties of CI in engine components construction is a lead way to techno-industrialization. Several methods such as heat treatment analysis of samples, corrosion test, investigation of material hardness, tensile stress, strain and the determination of modulus of elasticity of the sampled materials were carried out in this research. Established results obtained from practical examination showed appreciable improvement for material hardness and tensile stress. As percentage composition of CI to cow bone ash increases. However, the sampled specimens were found more corroded in sea water medium than the fresh water. The corresponding weight loss result of the specimens is from 33.77% – 5.44% for sea water and 7.28% – 3.62% for fresh water respectively over the test duration for the hybrid CI with cow bone ash. Other results are the rate of corrosion of the CI and cow bone hybrids where the sampled specimens in the sea water corrode faster than the fresh water. Conclusively, the carried out research is found to be feasible and it is recommended that the hybrid CI with cow bone ash be used for engine components construction to avoid unforeseen damages from engine block explosions, corrosion emission, etc.

Keywords — Bone ash, Cast iron, Corrosion, hardness test, heat treatment.

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I. INTRODUCTION

The use of CI for structural purposes, constructions and other vital engineering and technical applications cannot be over emphasized (Pankaj, 2017; Satnam, et al., 2019). The structure of CI is a composition of different metallic materials put together by the process of liquefaction. The end product from this process is the formation of CI. CI serves in different capacity in manufacturing and production industries. It is most often the raw material to the construction of engine components, such as cylinder heads, engine blocks, piston rings, flywheels, machine beds, brake drums, etc, (Attila et al., 2004; Salihu and Sulieman, 2018). Thus, the vital features of a CI in its numerous applications is subject to its good thermal conductivity, vibration damping ability and good machinability (Attila et al., 2004; Salihu and Sulieman, 2018; Mousa and Daniel, 2014). Cast irons are of various types but the most commonly used in engineering is the grey CI. Hence, the selection criteria of a CI for engineering applications are based on good resistance, weight consideration, low cost, compressive strength, exhibition of fairly high temperature, high fluidity for easy shaping to complex form, etc (Salihu and Sulieman, 2018).

Inspite of these numerous advantageous factors surrounding CI, the said engineering material is seriously liable to corrosion in its application in sea-water and other medium (Ojo and Abimbola, 2019; Ojo et al., 2020). A scholarly report affirms that the cast iron mostly made of grey deforms and fracture, thus; corrodes and wear-off due to its weak nature in its molecular composition (Pankaj, 2017). Corrosion is a limiting factor militating high rate of organizational spending. It is the destructive degradation of CI and other engineering materials like metals and alloys. It can cause unplanned shutdown and jeopardize the technological progress of engineering equipment (Ojo and Abimbola, 2019). A reviewed study attest to this fact and confirmed the cost implication of engineering materials corrosion in the US as high as $300 billion per year. This could be reduced by the application of innovative technology from material scientists (Ojo and Abimbola, 2019).

Conversely, improving CI material optimization for the design production of engine components is the heart beat of this research paper. This needful act will tend to reduce unplanned downtime and maintainability but rather increase durability and availability of an engineering equipment. Hence, the experimentation of hybridizing CI with animal ashes will reinforce CI against corrosion and other similar deteriorative elements. This is the pivotal aim of this paper. Thus, the hybridization of animal ashes with engineering materials is a new innovative technology in the engineering industry. Studies revealed that ashes of animal bones such as cow from abattoir wastes are used as alternative and replacement of lime and limestone dust to improve the engineering properties of asphaltic concrete mixtures in construction of flexible pavement roads (Modupe et al., 2019). Similarly, a revealed investigation attests that the ashes from cow bone have been proven as reinforcement agents in polyester for the development of polymer based composites for structural application (Temitope and Isiaka, 2015). No doubt, the trend of research is towards the production of automotive engine blocks with network polymers which comprises of vital mechanical properties with graphite fiber reinforcement (Namata, 2015).

Consequently, a deep research into studying CI hybrids and relative organic wastes such as the ashes of animal bones are imperative features for the development and improvement of corrosion resistance engine components. Therefore, the study is to bridge the gap of improving the tensile properties of the hybrid CI. This will allow it to operate at higher pressures, effective improvement in the combustion process to reduce the emission of pollutants.

II. EXPERIMENTATION

In order to achieve the goals of this research paper, a practical evaluation of CI and selected animal bone ashes were put together for experimentation as shown Figs 1 – 3.

Fig 1: Sample of Cast Iron

Fig 2: Ashes of cow bone

Fig 3: Ashes of goat bone

These selected specimens of animal bones were sourced from the Edepie cow slaughter in Yenagoa metropolis, Bayelsa State. The reason for the selection of the two bones is to make a close comparative analysis in terms of their chemical composition so as to choose the sample with richer chemical properties. Meanwhile, the animal bones were dry-oven and grinded in the Niger Delta University chemical engineering laboratory equipment as shown in Fig 4.

Fig 4: Boekel Chemical Dryer and Oven

Consequently, a tabular information in table 1 describes the bone chemistry of the selected animal bones and the cow bone is obviously selected due to its reported chemical composition.

Table 1: Chemical Composition Report of Animal Bone

Chemical Compound	Cow	Goat Bone
Calcium Oxide (%)	37	28.11
Phosphorus	18.03	16.71
Water Content (%)	1.71	1.79
Melting Point Temperature (^{0}C)	350	330
Density (g/cm^3)	2.16	2.23
Sodium (%)	3.5	-
Sulphur (%)	1.78	-
Potassium (%)	3.29	0.44
Magnesium (%)	-	0.58

III. Heat Treatment

The selected specimens were subjected to heat treatment process to test for the corresponding thermal characteristics to ascertain its acceptability. They were introduced to the furnace to determine the material melting temperatures; meanwhile, their weights were measured before and after the experiment. This is carried out with the samples placed in a 33.56g crucible plate inserted into the furnace as shown in Fig 5. The crucible plate allows the specimens to liquefy inside it at their respective melting temperatures. After liquefaction, the materials in the crucible plate are brought out for measurement to determine their weight differences with an electronic compact scale shown in Fig 6.

Fig 5: Specimens inside Heat Treatment Furnace

Fig 6: Electronic Compact Scale

The process continued with the combination of CI and the ashes of cow bone by percentage ratio as shown in table 2.

Table 2: Order of CI /Ashes of Cow Bone Experiment

Materials	Percentage Composition (%)	
	CI	Bone Ash
CI /Bone Ash	99	1
CI /Bone Ash	98	2
CI /Bone Ash	97	3
CI /Bone Ash	96	4
CI /Bone Ash	95	5
CI /Bone Ash	90	10
CI /Bone Ash	85	15
CI /Bone Ash	80	20
CI /Bone Ash	75	25
CI /Bone Ash	70	30

IV. DETERMINATION OF CORROSION RATE

The test specimens in this research work was subjected to corrosion examination where materials are meant to undergo a total immersion test analysis. This test is carried out due to its effectiveness in evaluating metals corrosion. Conversely, a MH – Series Pocket Scale equipment shown in Fig 7 was used for specimens measurement before and after immersion test analysis in sea and fresh water medium respectively.

Fig 7: MH – Series Pocket Scale

Thus, the measurement of the specimens was all based on weight loss, density, area and the exposure time of the corresponding corrosion rate which is calculated using the governing equations in equations 1 and 2. Meanwhile, the corrosion test bed for the experimentation is shown in Fig 8.

$$R_{corr.} = 87.6 \times 10^4 \left[\frac{W}{DAT}\right] \quad 1$$

$$\% \, weight \; loss = \frac{W_o - W_f}{W_o} \times 100\% \quad 2$$

Where,

R_{corr} = Corrosion rate
D = Density
A = Cross Sectional Area
T = Exposure Time
W_o = Original weight of specimens before corrosion test
W_f = Final weight of specimens after corrosion test


Fig 8: Corrosion Test Bed

V. HARDNESS TEST

The hardness of a material is the resistance to penetrate through an object. This property of a material is to resist indentation and wear. Thus, the objective of this test is to identify the level of resistance of the test samples used in the experimental process. Therefore, in order to achieve this purpose, Universal Testing Machine as shown in Fig 9 is used in carrying out the prescribed experiment with the aid of Vernier calliper in Fig 10 for smaller measurement of distance. The practical procedure carried out according to the Brinell hardness test process. In this test method, a ball made of hardness steel is used as test body. The ball is pressed onto the sample with a defined test force which depends on the diameter of the ball and test material, where measurement of the impression of the ball is taken. The hardness of the material according to Brinell is calculated from the test force, F and the surface diameter, D of the ball with the impression diameter, d caused by the impression of the ball on the material as shown in the hardness governing expression in equation 3.

Fig 9: Universal Testing Machine

Fig 10: Vernier Calliper

$$Material\ Hardness = \frac{0.102F}{0.5\pi\ D\ (D-\sqrt{D^2 - d^2})} \quad 3$$

VI. RESULTS PRESENTATION AND DISCUSSION

Presented in table 3 is heat treatment result for the CI and the ashes of the cow bone with corresponding melting temperatures of 1204°C and 350°C respectively. Thus, this result enables the evaluation of the percentage composition ratio of the specimens at the appropriate temperatures for complete liquefaction of samples.

Table 3: Heat Treatment Results

Materials	Melting Point Temperature (^{0}C)	Mass of Specimens (g)		Weight Difference (g)
		Weight before Heating	Weight after Heating	
Cast Iron	1204	47.71	31.24	16.47
Ashes of Cow Bone	350	25	13.42	11.58

Subsequently, table 4 presents heat analysis results of CI in combination with the cow bone ash in varying percentage ratios.

The weight percentage composition results in terms of ratio of CI to the bone ash before and after the heat treatment is shown in Figs 11. The two curve plots demonstrate linearity as the ratio progresses. The result interprets the acceptability of bone ash as reinforcement to CI which will eventually enhance the production of engine component.

Table 4: Percentage Composition of CI /Cow Bone Ash at Melting Temperature of 1204^{0}C

Percentage Composition (w%)		Mass of Specimens (g)		Weight Difference (g)
CI	Cow Bone Ash	Weight before Heating	Weight after Heating	
99	1	10	9.89	0.11
98	2	9.1	8.49	0.61
97	3	9.2	9.33	-0.13
96	4	12.64	12.96	-0.32
95	5	13.39	13.58	-0.19
90	10	16.64	16.65	-0.01
85	15	19.41	19.45	-0.04
80	20	20.87	21.43	-0.56
75	25	21.5	22	-0.5
70	30	10.28	10.48	-1.2

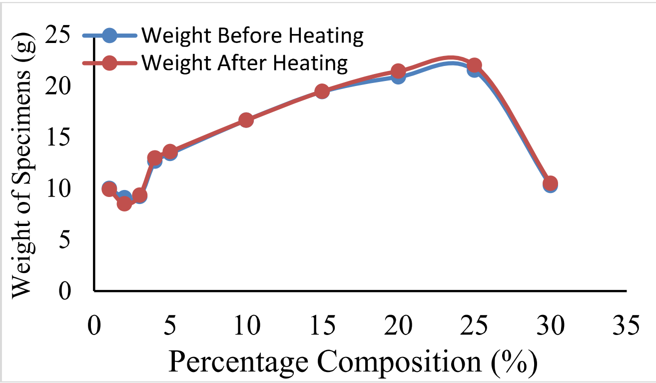

Fig 11: Graph Plot of Percentage Composition

Similarly, graphical plots of corrosion rate analysis of the specimens in the fresh and sea water testing medium are presented in Figs 12 – 15.

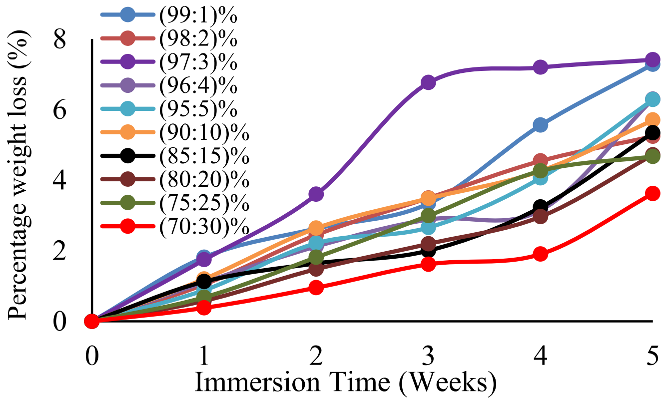

Fig 12: Weight Percentage of CI /Bone Ash in Fresh Water

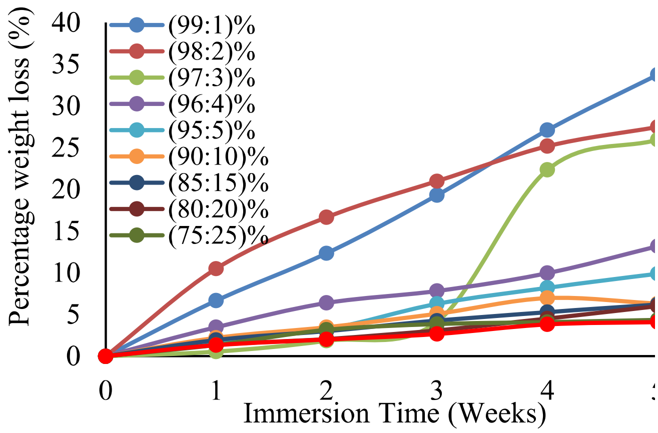

Fig 13: Weight Percentage of CI /Bone Ash in sea Water

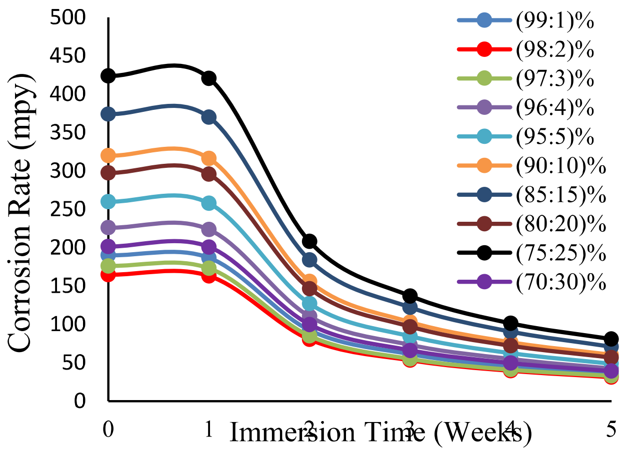

Fig 14: Corrosion Rate Analysis of CI /Bone Ash in Fresh Water

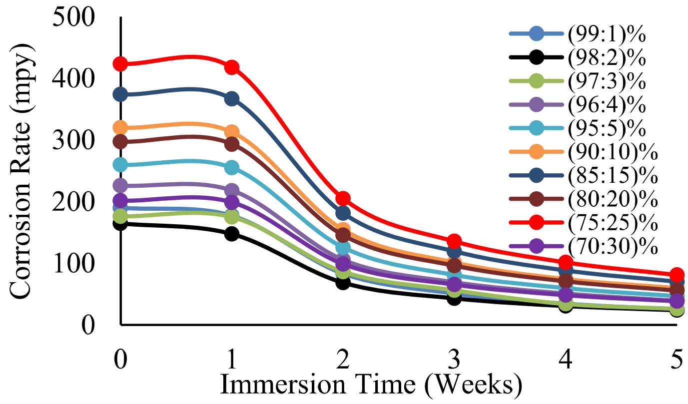

Fig 15: Corrosion Rate Analysis of CI /Bone Ash in Sea Water

The graphical results of corrosion rate analysis and percentage weight loss against time of immersion of the sample in the testing medium describes the thermodynamic capacity of specimens in engineering applications. It is observed that the weight loss in percentage in seawater for the specimens is higher than the fresh water medium under the same ratio consideration of the cast iron to bone ash combination. Results show specimens weight loss of 33.77%, 27.51%, 25.95%, 13.18%, 9.90%, 6.30%, 6.21%, 6.01%, 5.44% and 6.29% at sea water and a corresponding trend for fresh water as 7.28%, 5.24%, 7.42%, 6.29%, 6.28%, 5.7%, 5.34%, 4.72%, 4.67% and 3.62% as presented in Fig 12 and 13 respectively.

Similarly, results attest that sampled specimens corrodes more in sea water than fresh water. Thus, in a summarised result for corrosion rate for sea and fresh water is 25.16mpy against 35.23mpy at a ratio of 99% of CI to 1% of bone ash composition. Conversely, in a progressive ratios of (98:2)%, (97:3)%, (94:6)%, (95:5)%, (90:10)%, (85:15)%, (80:20)%, (75:25)% and (70:30)% of CI to bone ash composition; corresponding results for sea water are 23.90mpy, 26.09mpy, 39.23mpy, 46.83mpy, 59.97mpy, 70.15mpy, 55.90mpy, 80.10mpy and 37.77mpy. Similarly, for fresh water the corrosion rate obtained are 31.24mpy, 32.62mpy, 42.34mpy, 48.72mpy, 60.36mpy, 70.81mpy, 56.67mpy, 80.76mpy and 38.84mpy respectively. However, the increase in percentage composition of the bone ash on the CI reduces the corrosion rate.

The hardness and tensile test results of the materials under study are presented in table 5 with the aid of the governing equation as shown in equation 3. The presented test results for the material hardness and tensile test analysis affirms to the review literature. Consequently, percentage composition of the cow bone ash to the CI test analysis reveals that the bone ash is identified as a reinforcement agent and it is capable of improving the mechanical properties of the ordinary CI in terms of its stress – strain characteristics.

Table 5: Universal Tensile Test Results

Cast Iron/ Bone Ash Composition	Applied Force (N)	Material Stress Analysis			
		Tensile Stress (σ) MPa	Strain (ε) δl/L	Ductility (%)	Modulus of Elasticity (*E*) Mpa
99:1%	9550	143.603	0.978	2.222	146.794
98:2%	9710	146.966	0.96	4.205	153.145
97:3%	9965	151.485	0.902	10.909	168.011
96:4%	10280	156.959	0.893	12.025	175.833
95:5%	10310	158.109	0.889	12.469	177.824
90:10%	10550	162.503	0.886	12.919	183.497
85:15%	10750	167.05	0.885	12.984	188.739
80:20%	10890	170.353	0.87	14.904	195.743
75:25%	11150	175.196	0.861	16.129	203.454
70:30%	11325	177.946	0.856	16.883	207.989

It is affirmed from the tabular results as shown that as the applied force increases down the percentage composition ratio of the CI /bone ash, the tensile stress, strain and the modulus of elasticity both increases with a rise in percentage ductility. The ductile characteristic feature confirms that the added load up to 11.325KN to the testing specimens will not fracture the material even as high as 16.883% which is a corresponding percentage composition of (70:30)% of CI to bone ash. Another affirmed factor is the young modulus of elasticity which is a numerical value of tensile stress that is applied to a metallic material that will increase its length as the material remains perfectly elastic throughout such an excessive strain. Thus, the young modulus of elasticity is defined within a range of values for CI as (100 – 160)MPa (Khurmi, 2004). However, the test result for the CI /bone ash confirms this value for the modulus of elasticity to be (146.794 – 207.989)MPa within the defined percentage composition. Perhaps, these set of results seems to improve due to the reinforce CI with the bone ash. Similarly, it is observed that the fracture diameter gradually reduce as the percentage composition increase to (70:30)% of CI to bone ash.

Finally, the obtained results from the practical section confirms some level of improvement of the CI as cow bone ash is combined with it to serve as reinforcement substance. It confirms some level of enhancement in terms of hardness, corrosion resistance, improved modulus of elasticity, tensile stress, ductility, etc. Therefore, the reinforced CI with good percentage of animal bone ash will stand the test of time to be used for the design and construction of engine components in the engineering industry.

VII. VALIDATION OF RESULTS

The research work carried out could be validated using Ojo et al (2020) to improve the structural properties of CI in order withstand engineering material stresses. Also to enhance the production of engineering components and ensuring their durability.

VIII. CONCLUSION

The study of reinforcing CI with ashes of animal bone for effective production of engineering materials will resist some amount of regular engine components degradations. Therefore, it is evidently obvious to conclude that:

- The combination of CI with ashes of animal bone is a good hybrid for the production of machine parts and components.
- The hybrid is also confirmed as a good corrosion resistance mostly in salty medium like the sea water.
- Study also affirms the use of animal waste such as animal bone as substitute to improve the desired properties of metallic materials for engine components construction.
- This also creates waste conversion, thus promoting synergy in an abattoir wastes not only as a replacement to lime and limestone to improve the engineering properties of asphaltic concrete mixtures in road construction industries as stated in the literature (Modupe et al., 2019); but also as means to improve metallic properties.

IX. RECOMMENDATIONS

The result findings from this research will proffer solution to future failure and deterioration of CI used for the production of engine parts.

REFERENCES

Attila, D.; Vasilios, F. and Ingvar, L.S. (2004). Microstructure and Tensile Properties of Grey Cast Iron, Research Report: School of Engineering, Jonkoping University, Sweden. ISSN:1404 – 0018.

Khurmi, R. S. (2004). Strength of Materials (Machanics of Solids). S. Chand and Company LTD, Ram-Nagar, New Delhi, India.

Ojo, S. I. F. and Abimbola, P. I. P. (2019). Corrosion propagation challenges of mild steel in industrial operations and response to problem definition. *International Conference on Engineering for Sustainable World - Journal of Physics*, 1378(2019). https://doi.org/10.1088/1742-6596/1378/2/022006.

Ojo, S. I. F., Adedamola, S., Itopa, G. A., Abimbola, P. I. P. and Oluranti, A. (2020). Improving the structural properties and corrosion behaviour of electroless deposited Ni–P–Zn coatings on mild steel for advanced processes. *AIMS Materials Science,* 7(4), 441–452. https://doi.org/10.3934/matersci.2020.4.441.

Modupe, A.E.; Olayanju, T.M.A.; Atoyebi, O.D.; Aladegboye, S.J.; Awolusi, T.F.; Busari, A.A.; Aderemi, P.O. Modupe, O.C. (2019). Performance evaluation of hot mix asphaltic concrete incorporating cow bone ash (CBA) as partial replacement for filler, *IOP Conf. Ser.: Mater. Sci. Eng.* 640, 012082. https://doi.org/10.1088/1757-899X/640/1/012082.

Mousa, J. and Daniel, L. (2014). Application of cast Al–Si alloys in internal combustion engine components, *International Materials Reviews,* 59(3),132-158. https://doi.org/10.1179/1743280413Y.0000000027

Pankaj, A. (2017). Engineering Materials and Additive Processes Used in Automotive Engine Blocks. *International Journal of Advances in Scientific Research and Engineering (IJASRE),* 3(4), 151-161.

Salihu, S. A. and Sulieman, Y. I. (2018). Effects of Mould Additives on Hardness Property of Grey Cast Iron, *International Journal of Scientific Research in Mechanical and Materials Engineering*, 2(5), 72-78.

Satnam, S., Praveen, S., Dheeraj, G., Vivek, J., Rohit, K. and Sarbjeet, K. (2019). Development and characterization of microwave processed cast iron joint. *Engineering Science and Technology, an International Journal*, 22, 569–577. https://doi.org/10.1016/j.jestch.2018.10.012.

Temitope, A. and Isiaka, O. (2015). Effect of Cow Bone Ash Particle Size Distribution on the Mechanical Properties of Cow Bone Ash-Reinforced Polyester Composites, *Chemistry and Materials Research*, 7(3), 40-46.

Namata, S. (2015). Using Polymers as the Main Material in Engine Blocks and Components. *Journal of Applied Mechanical Engineering* , 4(5), 1-4. https://doi.org/10.4172/2168-9873.1000182.

