M. Giorgetti et al. (Eds.)

doi:10.3233/ATDE240641

Corrosion and Wear Properties of Aluminium AA7075 Reinforced Chitosan

N. E. UDOYE [a,1], E. O. ANIEMEKA [a], D. O. WACHUKWU [a] and S. T. A. OKOLIE [b]
[a] *Department of Mechanical Engineering, College of Engineering, Covenant University Ota, Lagos state, Nigeria*
[b] *Department of Mechanical Engineering, College of Engineering, Gregory University Uturu, Abia State, Nigeria*

Abstract. This study explores the mechanical behaviours of AA7075/chitosan composite at a mesh size of 90µm formed through percentage range of 3, 6, 9, and 12 wt. % by stir casting method. SEM revealed existence of grain at the borderline of the matrix as increased in reinforcing agent resulted to evenly dispersal of fibre links in the micrograph. XRD analysis showed existence of Hydroxyapatite, $Ca_{10}(PO4)_6(OH)_2$, as seen by many high-intensity peaks in the diffract gram of the dominant crystal. The wear rate of the samples is seen to be increasing from the control, peaking at 1.78 % at AA7075+9 wt. % chitosan before dropping by 0.04 % at AA7075+12 wt. % chitosan. The corrosion study revealed that AA7075+9 wt. % chitosan exhibits minimal corrosion rate in comparison to other matrixes. The findings shows that chitosan-reinforced AMMC can be produced using a cost-effective stir casting process while still meeting design requirements for use in electrical cables due to improved mechanical strength and electrical conductivity, as well as lightweight household utensils due to chitosan's antibacterial properties.

Keywords. AA7075, chitosan, stir casting; SEM, XRD, mechanical properties

1. Introduction

Aluminium matrix composites are important and can replace traditional monolithic materials but are rarely used [1, 2]. As a result, many decisions have been made in composites with reinforced materials that are inexpensive and just as reliable in terms of strength and resistance to abrasion as synthetically reinforced composites (i.e., silicon carbide) [3, 4, 5]. Corrosion-related costs account for a significant proportion of the country's GDP (gross domestic product) and GNP (gross national product) IP-related costs, resulting in higher maintenance costs as degraded metals are periodically or continually replaced [6, 7]. Metal Matrix Compounds (MMCs) are synthesized substances comprising of multiple constituent elements. This material is usually made up of metal, and the others could be alternative steel, an enamel, or a carbon-based compound [8, 9, 10]. A matrix is a continuous material into which the fortifications and reinforcements are embedded [11, 12, 13]. They have the unique potential to deliver a mix of qualities that are impossible to find in pure metals. [14]. (MMCs) is as a result

[1] N.E. UDOYE, Corresponding author, Department of Mechanical Engineering, College of Engineering, Covenant University Ota, Lagos state, Nigeria; E-mail: nduka.udoye@covenantuniversity.edu.ng.

of the inherent mechanical utilities in low-weight materials, such as the superiority of its quality, pliability and heat-resisting capacity [8]. Aluminium aggregates constitute the synthesis of aluminium with other metallic alloys and substances [15]. The addition of diverse alloys to the aluminium constituent gives improved aluminium properties, which results in improved metallic-deterioration retardant, enhanced cohesion and elasticity, better concentration, and improved sustainable constituents' properties in a diversity of variations and compositions [16]. Regardless of its composites, aluminium exhibits a spectacular combination of qualities, recalling that it is the best, most flexible, and associated with a metallic substance applied for several vocations, from subtle usage to other diverse mechanical applications [17]. Using aluminium rather than conventional materials for automobile assembly helps to reduce weight as well as emissions when specifically used in the assembly of motor parts [18]. Aluminium-alloys are frequently used as base materials in acids, salts, and other electrochemically damaging environments and have been mixed with low-cost fortification particles to create long-lasting aluminium particle composites. [19, 20]. For this experiment, the reinforcement material (Chitosan) was chosen due to its properties and distinct features. Chitosan made by treating chitin with an alkaline substance, such as sodium hydroxide), gotten from Micropogonias Undulatus i.e. croaker fish was chosen to reinforce aluminium alloy with a particle size of 90μm using weight fractions of 0%, 3%, 6%, 9%, and 12%. The aim is to study the impact of chitosan as a reinforcement material for aluminium alloy AA7075.

2. Materials and Methods

2.1. Sectioning

The metal matrix selected in this experiment is AA7075 alloy. It is a rainfall-solidified aluminium alloy with silicate and dolomite as the main intermetallic constituents. It is among the foremost popular aluminium for all usage. The automated cutting machine was used to slice the aluminium 7075 slabs, and soluble oil was distributed as a lubricant and coolant to reduce heat and metal deformation. Aluminium 7075 was cut into various weights of 97 %, 94 %, 91 %, and 88 %.

2.2. Preparation of Reinforced Aluminium Composite

The fish scale was sourced from the restaurant and were carefully washed with water and detergent to eradicate oil and other surface impurities. The dry scales were ground to a smooth powdery form using a grinding machine and separated to a different weight of 3, 6, 9, and 12g at 90μm sieve size. After producing the reinforcement particle, they were sent to the foundry to undergo the mix moulding procedure in order to create the new composite substance, the aluminium metallic pattern composite. The matrix was heated to a liquified state at 810 °C using a quarry heater followed by injection of magnesium into the matrix as a wetting agent. Furthermore, the reinforced agent was heated for an hour to a temperature of 700 °C. All reinforcing particle additions were carried out using the weight proportions specified for each aluminium weight. The characteristics were altered as the aluminium metal matrix was transformed into an aluminium metal matrix composite. As a result, characterization has changed, and new tests must be performed on the newly created composite in order to get its own characterization. SEM/EDS tests, XRD tests, Micro-hardness tests, and other tests were performed on the metal matrix to characterize them. Figure 1 shows the dried fish scale, and table 1 shows the reinforcement weight parameter.

Figure 1. Dried Fish scales.

Table 1. Reinforced Weight Measures.

Sample	Designation	Chitosan (%)	AA7075 (%)
AA7075	Control	0	100
	3 wt.% Chitosan	3	97
	6 wt.% Chitosan	6	94
	9 wt.% Chitosan	9	93
	12 wt.% Chitosan	12	88

3. Results and Discussion

3.1. Mechanical Properties

3.1.1. Hardness for AA7075/Chitosan Composites

The samples were placed under compressive stress to measure and determine their surface-to-core hardness property using a micro-hardness tester. From figure 2, AA7075 has a hardness point of 104.69HRB, which increased to 114.42HRB (Al+3g chitosan) then 138.11HRB (Al + 6g chitosan); before reaching the peak of 143.02HRB (Al + 9% chitosan) before decreasing to 104.70HRB. It was observed that aluminium alloy reinforced with 9% weight reinforcement has improved and best hardness property in comparison to other matrixes.

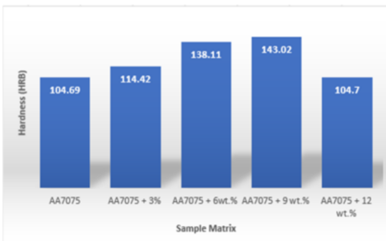

Figure 2. Analysis of Hardness Property.

3.2. SEM/EDS

Figure 3 depicts SEM/EDS spectrum of the control sample. The SEM sample image was taken at a magnification of 10,000x, with an electron energy of 15 kV and a horizontal field width of 124 μm at a working distance of 10.8 mm. The SEM result showed the existence of cavities including other insignificant elements. EDS analysis showed the elemental composition of calcium, alumina, oxygen, silicon, and alumina with other minor elements.

The SEM/EDS of AA7075/ 3% Chitosan is revealed in figure 4a. From the SEM, fibrous particles of approximately 0.2 microns thick are inoculated in the matrix. Furthermore, it was observed that there is uniform dispersal of particles in the composite matrix with little voids of 2.6 microns. The rich fibrous particles dispersed in the matrix increase the tensile intensity of the aggregate material by transmitting strain evenly to the alloy matrix. The EDS of figure 4(a and b) show that the composite is rich in Calcium, Silicon, Oxygen, Alumina and Carbon and contains a sparingly amount of iron and magnesium elements. The high content of silicon and calcium is responsible for the material's mechanical strength.

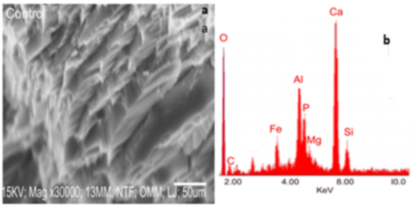

Figure 3. (a) Micrograph of the Control Sample (b) EDS of Sample.

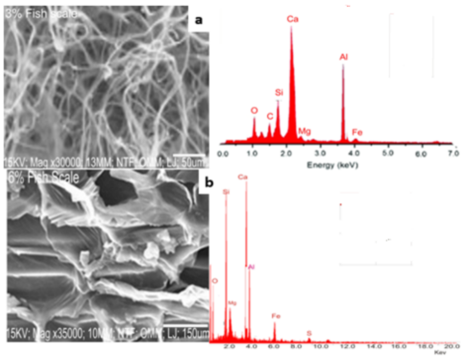

Figure 4. (a and b) SEM/EDS image of AA7075/Chitosan.

Figure 5c shows the SEM/EDS of the AA7075/ 9 wt. % chitosan composite. Figure 5d shows the SEM/EDS of AA7075/12 wt. % chitosan which showed existence of pores in the micrograph of the matrix. The fracture is a result of handling after the stirring was done. Furthermore, jagged boundaries containing reinforcements are observed as opposed to the 3 wt. % chitosan sample with well-defined grain boundaries. Thus, the reinforcement is responsible for providing support to the continuous alloy matrix, the material has improved tensile strength compared to unreinforced alloy.

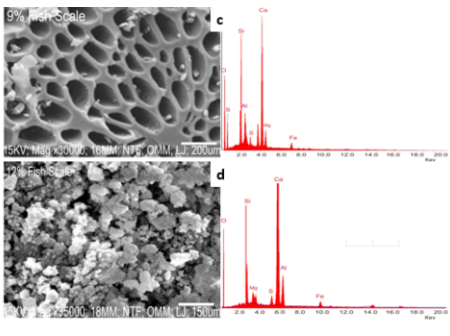

Figure 5. (c and d) SEM/EDS image of AA7075/Chitosan.

3.3. X-Ray Diffraction (XRD)

Figure 6 displays the XRD analysis of the control sample. The intensity counts up to 3000 against Bragg's angle, 2*θ*, between 10 degrees and 45 degrees. The patterns in the diffractogram shows the existence of different peaks of $CaCO_3$, $Ca_2Al_3SiO_4$, and $Ca(OH)_2$ which hardens indication of the existence of those compounds in the crystals assembly. The $Ca_2Al_3SiO_4$ peak indicates that the material was actually developed from AA7075.

Figure 7(a - d) show the quantitative structure of AA7075 with 3% to 12% of chitosan reinforcement. The biogenic crystal is evidence of chitosan obtained from fish scales as reinforcement material. The diffractogram shows multiple peak instances of crystalline phase: Hydroxyapatite, $CaCO_3$, and $Ca(OH)_2$, solidifying indication of their presence in the composite. The XRD peaks revealed the reinforcement materials used in this study, with Hydroxyapatite being a constituent crystal of bone and teeth for strength and rigidity.

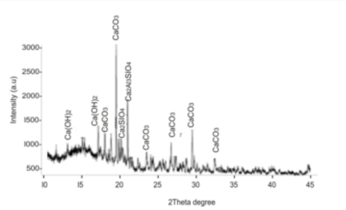

Figure 6. XRD Spectrum of the Control Sample.

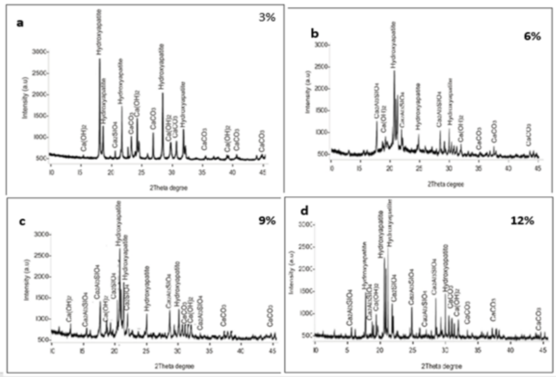

Figure 7. (a-d): XRD Spectrum of AA7075/Chitosan.

3.4. Wear Analyses for AA7075/Chitosan Composites

Table 2 shows the depreciation properties of the samples that were derived via a Pin-on-Disc Sliding Meter. From table 2 we can observe that the wear analyses were done under different ranges of measurements. The samples, from the control to the 12% chitosan composite, were tested with applied loads of 2N, 4N, and 6N, a velocity ranging between 0.4m/s to 0.6m/s and temperature of (20$\pm$4.5)0C to (26$\pm$4.7) 0C. The result shows that the sample with 9% of chitosan reinforcement with a wear rate of 0.33% is the lowest out of all the composite samples, with the control sample being the highest with a wear rate of 1.78%. One of the aims of this study is to determine the wear properties of AA7075 composites, and at the end of this experiment, it is examined that out of all aggregate materials, AA7075 with 9 wt. % chitosan is the best for use as it has the tendency to wear at a much slower rate than its companion composites. Figure 8 shows the wear rate as the percentage of reinforcement increases in the sample except for 12% reinforcement that failed to decrease its wear rates.

Table 2. Wear Test Analysis Using Pin-on- Disc Sliding Meter.

	Load (N)	Velocity (m/s)	Temp (^{0}C)	Test Pin Diameter (mm)	Total Distance	Humidity (%)	Disc Hardness (HRC)	Disc Surface Roughness Rc (um)	Wear Rate (%)
Control	2, 4, 6	0.6	26±4.6	10	1000	46±5.4	58	0.1±0.03	1.78
6% Fish	2, 4, 6	0.4	26±4.6	10	1000	44±5.5	58	0.1±0.02	1.62
9% Fish	2, 4, 6	0.6	20±4.5	10	1000	40±5.2	58	0.1±0.02	0.33
I2% Fish	2, 4, 6	0.5	26±4.7	10	1000	45±5.0	58	0.1±0.02	1.74

3.5. Corrosion Analyses for AA7075/Chitosan Composites

The Tafel extrapolated value of AA7075/9% chitosan investigated in 0.5M H_2SO_4 environment is shown in table 3 and figure 9. It was observed that AA7075/9% possesses the best corrosion resistance with the least corrosion rate. Utilizing a potentiostatic method, the corrosion characteristics of generated AA7075/chitosan compounds were investigated in settings. Table 3 and figure 9 display the tafel extrapolation value displaying corrosive perspective (Ecorr), corrosive flow frequency (jcorr), oxidation velocity (CR), and ionic conductivity (RP). According to table 3, AA7075/9% fish scale has the best oxidation barrier behaviour and the slowest corrosion rate. Undoubtedly, a degradation frequency of 18.47mm/year was achieved as opposed to the resist alloy's rate of 116.00 mm/year. Undoubtedly, AA7075/9% fish grit, AA7075/12% fish scale, AA7075/6% fish scale, AA7075/3% fish scale, and as-received alloy have inferior corrosive progression to the generated compound with inter-grain existence. It is obvious that the electrolytic reactions are greatly changed by the particle injected in the aluminium barrier. More specifically, the agro-based particulate's resistance action is connected to the creation of the adsorbents shield needed to delay the start of oxidation.

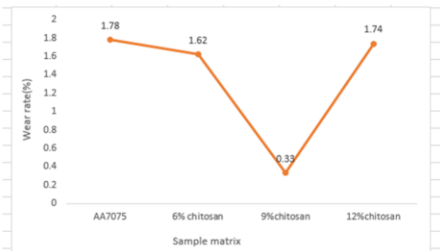

Figure 8. Wear rate of AA7075/chitosan.

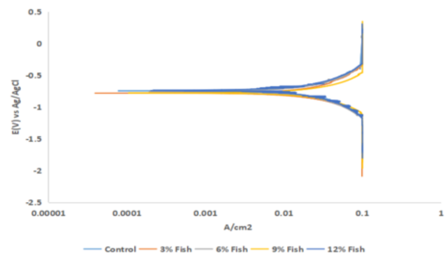

Figure 9. Potentiodynamic Polarization Curves for AA7075/Chitosan Composites.

Table 3. Potentiodynamic Polarization Results (AA7075/ Chitosan).

Sample	Ecorr(V)	Jcorr (μA/cm^2)	CR (mm/year)	PR(Ω)
Control	0.74	0.0099830	116.00	4.38
3% Fish	0.78	0.0072512	84.26	3.99
6% Fish	0.75	0.0048090	55.88	3.11
9% Fish	0.74	0.0015893	18.47	7.42
12% Fish	0.78	0.0028866	33.54	3.31

4. Conclusion

The results of this experiment have proven the hypothesis of this investigation. The deductions retrieved from the research include:

(a) The introduction of fish scales as reinforcement in aluminium alloy yielded positive results as a good matrix composite.

(b) There was extensive improvement of the aluminium alloy as it exhibited healthier characterization growth than the control sample.

(c) The deterioration frequency of the samples would have a rise and fall reaction to the agro-waste reinforcement which is seen in the analysis of the control and composite samples. It increases to the peak of 1.78 % at AA7075+9% wt. chitosan before dropping by 0.04 % at AA7075+12% wt. chitosan.

(d) The corrosion property of AA7075/9% wt. Chitosan composite were noticed to have the minimal erosion capability, minimal corrosion current mass, minimal weathering rate, and highest divergence resistance in comparison to other matrix samples

Acknowledgement

The authors will like to acknowledge the support of Covenant University for the publication Fund.

References

[1] Aynalem GF. Processing methods and mechanical properties of aluminium matrix composites. Advances in Materials Science and Engineering. 2020: 1-19.
[2] Olusesi OS, Udoye NE. Development and characterization of aa6061 aluminium alloy /clay and rice husk ash composite. Manufacturing Letters. 2021; 29: 34–41.
[3] Suresha B, Guggare SL, Raghavendra NV. Effect of TiO2 filler loading on physico-mechanical properties and abrasion of jute fabric reinforced epoxy composites. Materials Sciences and Applications. 2016; 7(9): 510-526.
[4] Cholewa M, Wróbel T, Baron C, Morys M. Surface phenomena at the interface between silicon carbide and iron alloy. Materials. 2021; 14(22): 6762.
[5] Inegbenebor AO, Bolu CA, Babalola PO, Inegbenebor OI, Fayomi OSI, Aluminum silicon carbide particulate metal matrix composite development via stir casting processing. Silicon. 2018;10(2): 343–347.
[6] Mazumder MAJ. Global impact of corrosion: Occurrence, cost and mitigation. Glob. J. Eng. Sci, 2020; 5(4): 0-4.
[7] Xhanari K, Finšgar M, Knez HM, Maver U, Knez Ž, Seiti B. Green corrosion inhibitors for aluminium and its alloys: A review. RSC Advances. 2017; 7(44): 27299–27330.
[8] Ramnath BV, Elanchezhian C, Jaivignesh M, Rajesh S, Parswajinan C, Ghias ASA. Evaluation of mechanical properties of aluminium alloy–alumina–boron carbide metal matrix composites. Materials & Design. 2014; 58: 332-338.
[9] Samal BP, Panigrahi SC, Sarangi B. Use of modified stir casting technique to produce metal matrix composites. Safety. 2013; 10(11).
[10] Udoye NE, Nnamba OJ, Fayomi OSI, Inegbenebor AO, Jolayemi KJ. Analysis on mechanical properties of AA6061/Rice husk ash composites produced through stir casting technique. Materials Today: Proceedings. 2021; 43: 1415-1420.
[11] Ramulu M, Rao PN, Kao H. Drilling of (Al2O3) p/6061 metal matrix composites. Journal of Materials Processing Technology. 2002; 124(1-2): 244-254.
[12] Lakshmikanthan A, Angadi S, Malik V, Saxena KK, Prakash C, Dixit S, Mohammed KA. Mechanical and tribological properties of aluminum-based metal-matrix composites. Materials. 2022; 15(17): 6111.

[13] Suleiman Khayal OE. Literature review on imperfection of composite laminated plates. Journal of Microscopy and Ultrastructure. 2017; 5(3): 119.
[14] Naseer A, Ahmad F, Aslam M, Guan BH, Harun WSW, Muhamad N, Raza MR, German RM. A review of processing techniques for graphene-reinforced metal matrix composites. Materials and Manufacturing Processes. 2019; 34(9): 957–985.
[15] Ramnath BV, Elanchezhian C, Jaivignesh M, Rajesh S, Parswajinan C, Ghias ASA. Evaluation of mechanical properties of aluminium alloy–alumina–boron carbide metal matrix composites. Materials & Design. 2014; 58: 332-338.
[16] Rajesh AM, Kaleemulla M. Experimental investigations on mechanical behavior of aluminium metal matrix composites. IOP Conference Series: Materials Science and Engineering. 2016;149(1): 012121).
[17] Raabe D. The materials science behind sustainable metals and alloys. Chemical Reviews. 2023; 123(5): 2436-2608.
[18] Butt J, Mebrahtu H, Shirvani H. Strength analysis of aluminium foil parts made by composite metal foil manufacturing. Progress in Additive Manufacturing. 2016: 93-103.
[19] Fayomi OSI, Babaremu KO, Akande IG. Impact of Al-Composites in the manufacturing industry: A necessity. International Journal of Civil Engineering and Technology. 2019;10(3): 72–82.
[20] Divakaran N, Das JP, Mohanty S, Ramadoss A, Nayak SK. Comprehensive review on various additive manufacturing techniques and its implementation in electronic devices. Journal of Manufacturing Systems. 2022; 62: 477-502.