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The Behavioral Corrosion Characterization of Aluminium AA6061/Chitosan Composites

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Abstract. The high cost and negative environmental impact of traditionally made aluminium metal matrix composites (AMMC) need their replacement with eco-friendly materials with improved mechanical characteristics. The repurposing of agricultural waste in innovative materials is critical to achieving a sustainable society. This study utilized AA6061/chitosan at sieve size of 90µm created via modified stir casting at weight proportions of 3, 6, 9, and 12 wt. %. The produced composites reached a maximum hardness of 60.2 HRB at 9wt. % chitosan, comparable to a 2.36 % improvement in AA6061 hardness, 57.4 HRB. Similarly, tensile strength increased with increasing chitosan particles, from 83.07MPa for the unreinforced alloy to a maximum of 114.92MPa for 12 wt. % AA6061 reinforcement with chitosan. The samples' XRD revealed clear evidence of Hydroxyapatite, $Ca_{10}(PO_4)_6(OH)_2$, a component of teeth and bones that provides strength. The corrosion characteristics findings reveal that AA6061+9 wt. % chitosan has the lowest corrosion rate of all the samples. In addition, the microstructure of AA6061 with chitosan strains of reinforcement was observed in the AA6061/3wt. % SEM, eventually filling grain boundaries of the metal with increasing reinforcements to provide evenly distributed fibrous links connecting AA6061 grain structure at 6wt. % and 9wt. % reinforcement in the micrograph

Keywords. AA6061, chitosan, SEM/EDS, XRD, corrosion, wear

1. Introduction

The swift development of the manufacturing industries has created a need for materials comprising better properties than conventional monolithic materials and improved sustainability. Aluminium alloys, due to exceptional strength and low density, toughness, and corrosive resistance are heavily relied on in the aerospace industries and structure-enrich metal matrix (MMC) composites, have attracted the interest of many scientists [1, 2]. The better way to preserve aluminium alloys placed in acute corrosion environments is to add a corrosion inhibitor to the solution in contact with the surface to control the corrosion reaction and reduce the rate of corrosion [3]. MMC outperform traditional materials in their capacity to adjust the final qualities of composites by using inherent features of constituent materials [4].

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There has been considerable advancement over the past few years in the construction of aerospace components for the implementation of the structure, motor and composite components [5, 6]. Mostly owing to the stronger corrosion, greater hardness and fatigue resistance they possess as compared to other materials, composite materials in the aerospace industry are increasingly used [7]. The desired characteristics, such as strong intensity and hardness, corrosion resistance, etc. in the finished item, are generally merged into different components [8]. Pure aluminium cannot be used in structural applications unless the substance contains other elements to obtain sufficient strength for the manufacture of structural elements. MMC is widely used in industrial processes, including light weight with stiffness, ultra-specific strength, ductility, and heat resistance [9, 10]. Fly ash, fibre, whiskers, and particles are some examples of bio-based waste particles that have recently been used as reinforcement [11,12]. Corrosion occurs at varying speeds and in a wide range of materials, including metals such as iron and copper, as well as non-metals such as ceramics and rubber [13,14]. Corrosion is a subject that receives a lot of attention since there is so much to gain from preventing it [15]. The surface morphology, hardness, tensile, percentage elongation, corrosion and wear rate of AA6061/Chitosan composite were studied by transferring chitosan particulates into the matrix alloy at percentage reinforcement ranging from 3 to 12 wt% in increments of 3 wt%. As the chitosan content in the matrix of AA6061/Chitosan increased, the physical, mechanical, and wear properties improved, but the material became less ductile. AA6061/Chitosan showed improved wear resistance due to the chitosan particles inclusion. The preparation of the chitosan particles reinforced aluminium alloy AA6061, the stir casting technique was used. Microhardness and UTS were enhanced in the AMCs by using chitosan particles.

2. Materials and Methods

2.1. Preparation of the Sample Specimen

The metal employed as a matrix in this experimentation is AA6061 alloy. The choice of sample is justified by its properties and economical value. For this experimentation, we will be utilizing AA6061 and figure 1 shows the dried chitosan to be used as reinforcement.

Figure 1. Dried Chitosan scales.

2.2. Proportion of Reinforcing Particle

Chitosan, produced from the deacetylation of croaker fish scales, was employed as a reinforcing particle in this study. After obtaining the fish scales from the various restaurants on campus, the scales were properly cleaned with water and liquid detergent to eliminate oil and other surface impurities. This was followed by a thorough rinse with water, then with distilled water, before being allowed to dry for three days. Using a grinding machine, the dry scales were crushed to a fine powder. They were then sieved to a particle size of 90μm (microns) and weighed into the necessary weight proportions of 0, 3, 6, 9, and 12g.

2.3. Preparation of Reinforced Aluminium Composite

The stir casting procedure for the manufacture of the composite entails taking the measured weights and placing them in their respective graphite crucible and heating them to molten states at 810°C using a pit furnace, after which magnesium was injected into the molten aluminium a wetting agent. Similarly, the reinforcement particles were heated for an hour to a temperature of 700°C. Finally, using a graphite stirrer, the reinforcement particles were injected into the molten aluminium alloy for unvarying circulations.

3. Results and Discussion

3.1. Hardness Property of AA6061/Chitosan

From figure 2, we can see that pure aluminium (control sample) has a hardness value of 57.4HRB, and the hardness quality of the resulting composites increased to the hardness value of 60.2HRB (Al + 9g chitosan) before dropping again to 55.2HRB (Al +12g chitosan). It is without denial that aluminium reinforced with a weight percentage of 9g produces a composite with the best hardness quality whereas, aluminium reinforced with a weight percentage of 12g produces a composite whose hardness quality is way below that of unreinforced aluminium.

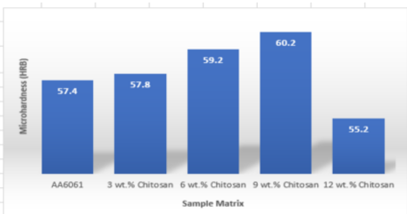

Figure 2. Hardness Test Result of Samples.

3.2. SEM/EDS Analysis of AA6061/Chitosan

Figure 3 shows the micrograph image and EDS spectra of the control sample. From this micrograph, voids are observed as well as other trace elements. The control sample was further studied using EDS and this revealed the element contents as well as their scale of supremacy in the control sample. The scale showed the supremacy of silicon, calcium, oxygen, alumina with other essential constituents. The EDS analysis result established the constituent elemental structure of aluminium alloy.

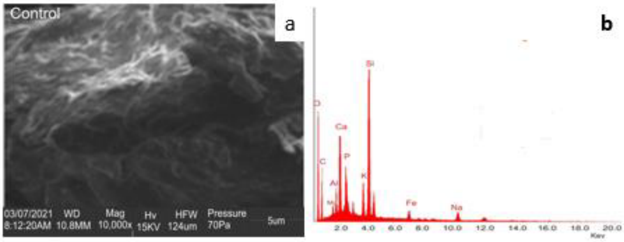

Figure 3. (a) Micrograph of the Control Sample (b) EDS of Sample.

3.2.1. SEM/EDS Analysis of AA6061 with 3 wt. % Chitosan

The SEM/EDS of the composite AA6061 with 3wt. % and 6wt % Chitosan is shown in figure 4. The structure represents strengthened composite thus would provide improved response to mechanically loading inform of tensile or hardness as a result of the reinforcing links within the boundaries. EDS results show a large presence of Calcium and Oxygen in the composite, with significant amounts of Silicon, Iron and Carbon; while sparing amounts of Magnesium is present in the sample. Results obtained revealed increasing calcium content and improved mechanical properties.

SEM/EDS of the composite, AA6061 with 9wt.% and 12wt % chitosan, is shown in figure 5. From the SEM, it was noticed that uniform dispersal of chitosan particles in the aluminium alloy (AA6061) base matrix occurred during fabrication. This is evident in the micrograph as the structure of the composite show chitosan particulates reinforced into the grain boundaries of the AA6061 alloy matrix for support.

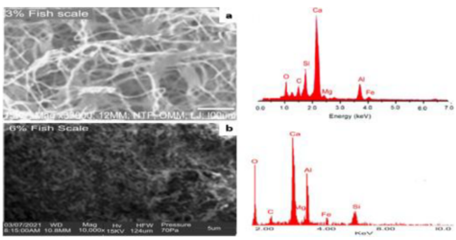

Figure 4. (a and b) SEM/EDS image of AA6061/3 & 6% Chitosan.

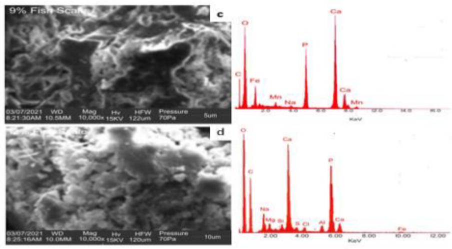

Figure 5. (a and b) SEM/EDS image of AA6061/9 & 12% Chitosan.

3.3. XRD Analyses of the AA6061 Samples

The casted samples were examined using XRD analysis in order to confirm the compounds were developed in the varying weight percentages reinforcements for the composites. A Rigaku D/Max-111C was used to perform this analysis.

3.3.1. XRD Analysis of Control Sample

Figure 6 shows the XRD analysis of the unreinforced alloy AA6061. The distinct hill-slope pattern in the diffractogram shows multiple instance occurrences of $CaCO_3$, $Ca_2Al_3SiO_4$, and $Ca(OH)_2$ solidifies evidence of the presence of those compounds in the crystalline structure. The $CaCO_3$ crystalline phase has an intensity of 3000. The $Ca_2Al_3SiO_4$ crystalline phase the material was indeed fabricated from aluminium alloy, AA6061.

The XRD analysis of the crystalline constituent of AA6061 with 3% to 12% of chitosan reinforcement is represented in figures 7(a - d). The diagram shows crystals diffracted between Bragg's angle, 2θ, of 10 degrees and 45 degrees and an intensity count slightly above 2500. Furthermore, the peak phases in the analysis are Hydroxyapatite, $Ca_2Al_3SiO_4$, $CaCO_3$, and $Ca(OH)_2$ respectively. This XRD pattern obtained proves the existence of particulate in composite. Also, it is observed that in the composite containing 9 wt. % chitosan has a higher intensity reading than that of the fabricated sample with 3 wt. %, 6 wt. % and 12wt % chitosan.

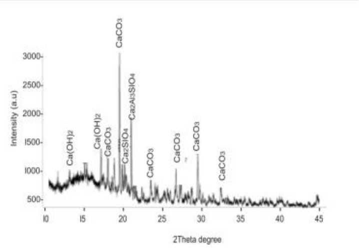

Figure 6. XRD Spectrum of the Control Sample.

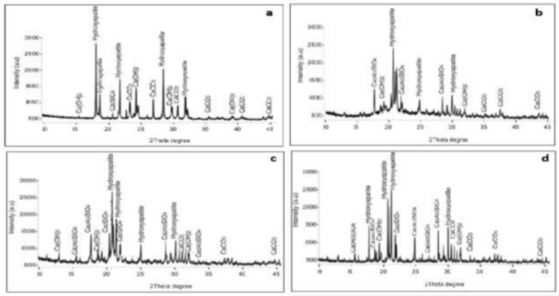

Figure 7. (a-d): XRD Spectrum of A6061/Chitosan.

3.4. Corrosion Analyses for AA6061/Chitosan Composites

Table 1 and figure 8 show the corrosion behaviour of AA6061/chitosan composites examined in environments using a potentiodynamic polarization route. Table 1 shows that AA6061/9% chitosan has the highest corrosion resistance character with a reduced corrosion rate. The corrosion rate of 0.18280 mm/year was achieved in comparison with 0.70453 mm/ year of the control as-cast aluminium alloy. It was observed that particles found in the aluminium borderline expressively change the electrochemical process.

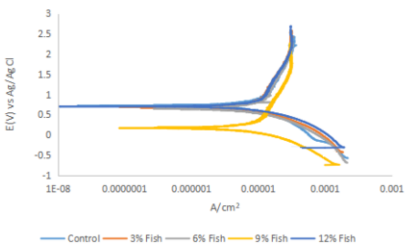

Figure 8. Potentiodynamic Polarization Curves for AA6061/Chitosan Composites

Table 1. Potentiodynamic Polarization Results (AA6061/ Chitosan)

Sample	Ecorr(V)	Jcorr (μA/cm2)	CR (mm/year)	PR(Ω)
Control	0.71805	6.0631E-05	0.70453	117.45
3% Fish	0.67620	4.0799E-05	0.47408	135.72
6% Fish	0.65056	4.0688E-05	0.41579	153.16
9% Fish	0.16692	0.0001E-04	0.18280	162.60
12% Fish	0.70067	2.5806E-05	0.29986	135.09

4. Conclusions

The conclusions that can be drawn from this study includes:

a) The use of agro-waste as reinforcements for a pure aluminium metal matrix was possible as the chitosan was effectively infused and the composites were created.
b) There was a significant increase in characterization properties of the composites as compared to the pure sample; which was observed as some composite samples exhibited better characterization than the pure sample
c) The corrosion characteristics of the generated AA6061/Chitosan composite were found to have the lowest corrosion rate of all the samples at AA6061+ 9 wt. % chitosan.

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