Crystal structure and corrosion properties of aluminium organoclay composite by the hotpress method

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Abstract. Aluminium Matrix Composite (AMC) is a material that has great potential especially in automotive industry. AMC has good corrosion resistance, density, electrical conductivity and heat properties. This paper will study the crystal structure form composite materials and the corrosion properties of the sample. Composite material made with Alumunium as a matrix and reinforcement in the of organoclay variations 0%, 1%, 2%, 3% wt by the hotpress method at 600°C for 1 hour. Characterization of crystal structure and phase using X-Ray diffraction. The corrosion properties of the samples were examine by potentiodynamic curves in 3,5 % wt NaCl solution. The results showed that the addition of weight percent composition of organoclay produce different characteristics and corrosion properties. Corrosion properties can be seen form the rate of corrosion slower along with the addition composition of the organoclay. The smallest corrosion rate results found in alumunium composites with reinforcement variations of 3% by 1,776 x 10⁻⁴ mm/year.

1. Introduction
The Developments in the field of materials science have been in the spotlight especially in the industrial and automotive industries. Especially advanced materials such as alumunium composite material. Alumunium Matrix Composite (AMC) is one of the material that has great potential because it has good mechanical properties such as hardness, strength, and high corrosion resistance. Further development of alumunium matrix composite can be strengthened by organoclay reinforcement [1].

Organoclay is clay soil that is modified using organic cation. This makes the clay properties change from hydrophilic to hydrophobic. The composite material is needed to fillers with high strength and hardness such as SiC, TiC, TiB₂, Al₂O₃, and SiO₂ [2]. Organoclay contains reinforcement of material such as Al₂O₃ and SiO₂ with a hardness value of 1 to 2 Mohs Scale, so that is can be a potential reinforcement for composite material [3].

The composite material will be done by the hotpress method. The Hotpress method will produce a composite with high density compared to conventional sintering, where there is a decrease in porosity and agglomeration of the reinforcement. The process parameters that need to be considered in the hotpress method it is temperature. Low hotpress temperatures can prevent agglomeration of reinforcement particles [4].

This paper will study the characteristics of crystal structures and phases formed on composites by using alumunium as a matrix and organoclay as reinforcement with variations composition 0%, 1%, 2%, 3% wt at 600°C hotpress temperature. Then also observed the electrochemical properties and corrosion rate of Alumunium/Organoclay with 3.5% wt solution.
2. Experimental Procedure

2.1. Material
The material used in this experiment is composite with Alumunium as a matrix and Organcolay (Montmorillonite) as a filler with different variations 1%, 2%, 3% wt, and without reinforcement as a base sample. Alumunium as a matrix and organoclay as a filler is mixed by the hotpress method at 600°C for 1 hour. Alumunium/Organoclay composite is made into 4 samples with a diameter of 2 cm and thickness of 0.5 cm.

2.2. Hotpress method
The result of mixing alumunium and organoclay with different variations 1%, 2%, 3% wt compacted inside a metal mold with a given pressure of 1 ton. The metal mold containing the composite is heated inside the furnace at 600°C for 1 hour. A similar process was carried out for alumunium powder without additional reinforcement organoclay.

2.3. Corrosion test
The Working Electrode and the Reference Electrode (Ag/AgCl) are used to quantify. Corrosion test data were collected out using Potentiostat. The solution used in the corrosion test was 3.5% wt NaCl according to the ASTM G44 standard. The corrosion test was carried out with 3 temperature conditions which we controlled 10°C, 25°C, and 40°C. The corrosion rate of each sample had been calculated after all data were collected from Potentiostat. The formula that used to calculated the value of corrosion rate is obtained [5].

\[ r = \frac{CMi}{np} \]  

Where C stands for the constant of corrosion rate (3.27 in mm/year), M stands for the atomic weight of every constituent in the alloy (g·mol⁻¹), i stands for current density (A/cm²), n stands for the number of electrons involved, ρ stands for a density of every constituent in the alloy (g/cm²).

3. Result and Discussion

3.1. XRD analysis
The XRD pattern obtained is by previous research conducted by Agung Seputra. Where in that study, the XRD pattern was obtained in Alumunium composites reinforced by organoclay (1%, 2%, 3% wt) at temperature variations [6]. Figure 1 shows the XRD pattern of Alumunium/Organoalay composite with different variations of reinforcement. The result of XRD shows the dominant phases present in the composite material. The aluminium phase is selected in the variation of the reinforcement. The

![Figure 1. XRD plot of aluminium/organolcay composite.](image)
organoclay phase is only found in Aluminium/Organoclay with 3% reinforcement, this is because the intensity of the organoclay phase is valued at the intensity of noise [7]. Besides that, the reaction of organoclay with other elements to form a new phase is one of the causes of the organoclay phase being detected.

The crystallite system of these samples is cubic, so the lattice parameters have the same value for a, b, and c. The lattice parameter is relatively fixed in all samples, followed by the same volume value in each variation of sample. The average crystal size of Aluminium/Organoclay composites is found by the Debye-Scherrer method.

| Table 1. Crystallographic parameters of the aluminium/organoclay composite. |
|---|---|---|---|
| Structural Parameters | Pure Aluminium | Aluminium/Organoclay 1% | Aluminium/Organoclay 2% | Aluminium/Organoclay 3% |
| Lattice Parameter (Å) | a=4.049 | a=4.049 | a=4.049 | a=4.048 |
| b=4.049 | b=4.049 | b=4.049 | b=4.048 |
| c=4.049 | c=4.049 | c=4.049 | c=4.048 |
| Crystal Structure | FCC | FCC | FCC | FCC |
| Space Group | Fm-3m | Fm-3m | Fm-3m | Fm-3m |
| Volume (Å³) | 66,425 | 66,408 | 66,486 | 66,313 |
| Cristallite Size, D (nm) | 84,681 | 72,843 | 77,352 | 83,796 |
| Strain | 0.445 x 10⁻³ | 0.019 x 10⁻³ | 0.055 x 10⁻³ | 0.173 x 10⁻³ |

In the Debye-Scherrer method there is a relationship between diffraction peak width and crystal size. Crystal size will decrease as the diffraction peak width increases according to the following equation [8].

$$D = \frac{k\lambda}{\beta \cos \theta}$$  (2)

Where D is the size of the crystal (nm), β is FWHM (radians), θ is the Bragg Angle, λ is the wavelength (1.54 nm) and k is a constant (0.94). The crystallite size and strain increase with the addition of reinforcement. In general, particles or impurities could restrain grain growth, that is why the strain values are relatively high as indicated in Table 1. Slight increase in the strain values were attributed to lattice defects. In the other words, it is caused the crystallite size to decrease and the strain to increase slightly [9].

3.2. Corrosion analysis

The data obtained in this test are the potential and the current to be plotted in the function of potential and current (E vs Log i). Then the curve of the plot results will be processed by connecting the linear lines between the anodic and cathodic to get the Ecorr and Icorr values [10]. Temperature variations in this corrosion test to show 3 conditions, cold, warm, and room temperature. Figure 2 shows an increase in corrosion potential following by increasing variations in the composition of reinforcement (organoclay).
Figure 2. Linear sweep voltammetry curves of (a) Al/Organoclay at 10°C, (b) LSV graph Al/Organoclay at 25°C (c) LSV graph Al/Organoclay at 40°C.

The increased corrosion potential as the increases proves that Aluminium/Organoclay composite is not easy to react with other compounds. Then, increasing variations in the composition of the reinforcement (organoclay) are followed by decreasing corrosion currents. Where this show that the Aluminium /Organoclay 3% has a higher corrosion resistance compared to Aluminium /Organoclay 1% and 2% at all temperature variations, because with the low value of corrosion current it means the electron transfer process in the material it will be slower so that composite material experience slower degradation.

Table 2. Data from the corrosion test of the aluminium /organoclay composite in the 3.5 wt%.

| Temperature | Sample            | \(E_{corr}\) (V) | \(i_{corr}\) (A) | Corrosion Rate (mm/year) |
|-------------|-------------------|------------------|------------------|--------------------------|
| 10°C        | Pure Aluminium    | -1.551           | 4.01 x 10^{-4}   | 3.201 x 10^{-2}          |
|             | Al/Organoclay 1%  | -1.492           | 4.37 x 10^{-4}   | 3.475 x 10^{-2}          |
|             | Al/Organoclay 2%  | -1.459           | 1.33 x 10^{-5}   | 1.052 x 10^{-3}          |
|             | Al/Organoclay 3%  | -1.361           | 1.96 x 10^{-6}   | 1.539 x 10^{-4}          |
| 25°C        | Pure Aluminium    | -1.558           | 1.454 x 10^{-4}  | 1.161 x 10^{-2}          |
|             | Al/Organoclay 1%  | -1.463           | 1.152 x 10^{-5}  | 9.157 x 10^{-3}          |
|             | Al/Organoclay 2%  | -1.480           | 4.214 x 10^{-5}  | 3.333 x 10^{-3}          |
|             | Al/Organoclay 3%  | -1.434           | 2.257 x 10^{-6}  | 1.776 x 10^{-4}          |
| 40°C        | Pure Aluminium    | -1.591           | 5.86 x 10^{-3}   | 4.683 x 10^{-2}          |
|             | Al/Organoclay 1%  | -1.611           | 3.61 x 10^{-3}   | 2.866 x 10^{-2}          |
|             | Al/Organoclay 2%  | -1.520           | 3.04 x 10^{-3}   | 2.405 x 10^{-2}          |
|             | Al/Organoclay 3%  | -1.458           | 2.99 x 10^{-3}   | 2.349 x 10^{-2}          |

Corrosion rate can be obtained using equation (1). Table 2 shows the result obtained that the addition of reinforcement (organoclay) affect the corrosion rate of composite material. Where decreasing the corrosion rate on composite material is followed by increasing reinforcement (organoclay).

4. Conclusion
The crystal structure from Aluminium/Organoclay composite is Face Center Cubic (FCC) with an Fm-3m space group. Aluminium phase found in all variation of composite material and organoclay phase is only detected in Aluminium/Organoclay 3%. The addition of the reinforcement affects the corrosion rate of composite material. The lowest corrosion rate is found in Al/Organoclay 3% variation with value of 1.539 x 10^{-4} mm/year (10°C), 1.674 x 10^{-3} mm/year (25°C), 1.776 x 10^{-4} mm/year (40°C).
Acknowledgments
The author thanks for the financial support from the Ministry of Research, Technology and Higher Education of Indonesia (RISTEK-DIKTI), under grant Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) No. NKB-2797/UN2.RST/HKP.05.00/2020.

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