Effects of variations in the addition of SiC\textsubscript{p} filler to corrosion rate of metal matrix composites (MMCs) Al-Cu-Mg/SiC\textsubscript{p}

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Abstract. We study of effects Al-Cu-Mg/SiC\textsubscript{p} Metal Matrix Composites (MMCs) with a matrix composition of 4.4 wt\% Cu, 1.8 wt\% Mg with SiC\textsubscript{p} fillers were varied (3.4; 3.7 and 4.0) wt\% and the remaining Al. SiC\textsubscript{p} is mixed into Al-Cu-Mg heated at 900\degree C, then stir casting is carried out at 250 rpm for 10 minutes. Then cooling is carried out to room temperature. After cold, heat treatment is given and continued testing. The SEM-EDX and XRD test results showed that the increasing SiC\textsubscript{p} content, the tendency for SiC\textsubscript{p} and Mg bonds to form the Mg\textsubscript{2}Si phase increased, making the sample items enlarge and appear coarser. While the corrosion rate test of increasing SiC\textsubscript{p} in the Al-Cu-Mg matrix makes Al-Cu-Mg/ SiC\textsubscript{p} samples tend to be more corrosion resistant. The event of declining corrosive properties is due to SiC\textsubscript{p} particles occupying grain boundary areas replacing O\textsubscript{2} (which provides corrosive properties) that are trapped in the sample during the cooling process.

1. Introduction

Research on Metal Matrix Composites (MMC) made from aluminum alloy for the aviation industry has been widely developed. The study used a varied matrix process and composition, aimed at looking at the physical and mechanical properties of the material and the results gave very good results [1–4]. The development of aluminum-based material composites was also carried out to obtain a more optimal performance by using matrix mixed methods with Silicon Carbide ceramic powder material (SiC\textsubscript{p}) and heat treatment [5–9]. However, SiC\textsubscript{p} has a small density compared to the matrix material in liquid conditioning, which is relatively difficult to mix. Then with the help of stircasting SiC\textsubscript{p} will be able to mix [10,11].

The variation of mixing Silicon Carbide into the aluminum matrix is possible to function as a filler that functions as a boundary filler between grains, thus expanding the touch surface between grains which makes the bond between the grains stronger [12–15]. The aluminum matrix coating method with SiC\textsubscript{p} with laser powder deposition has also been developed [16].

In this study Metal Matrix Composite (MMC) was made with Al-Cu-Mg material with Reinforce Silicon Carbide (SiC\textsubscript{p}) using the Stir Casting method, by making SiC\textsubscript{p} variations in the matrix and their impact on the corrosion rate.
2. Method
Preparation of Al-Cu-Mg / SiCp Metal Matrix Composites (MMCs) with a matrix composition of 4.4 wt% Cu, 1.8 wt% Mg with SiC fillers varied (3.4; 3.7 and 4.0) wt% and the rest Al. Before Al-Cu-Mg was mixed into SiCp, SiCp fillers were preheated at a temperature of 900°C, the purpose of which was to provide a wetting effect to dissolve easily into the Al-Cu-Mg matrix. Then mixing the Al-Cu-Mg matrix with SiCp filler at 900°C with stirring at a speed of 250 rpm for 10 minutes. After casting, cooling is continued. then annealing process was carried out at a temperature of 450°C for 2 hours and continued aging at a temperature of 160°C for 16 hours. The microstructure and commodity observations formed were carried out by SEM-EDX testing, and testing of corrosive properties to see the corrosion rate of the sample.

3. Result and Discussion
3.1. Microstructures
Microstructure testing using SEM-EDX Jeol jsm 6510LA machine. with a magnification of 2000 times. From the SEM observations, the surface of the Al-Cu-Mg / SiCp 3.4 wt% surface appears smoother when compared with the Al-Cu-Mg / SiCp 3.7 wt% sample and the Al-Cu-Mg / SiCp 4.0 wt% sample. From the EDX results it was found that the SiCp 3.4 wt% SiCp phase composition was detected, but in the sample with SiCp 3.7 wt% and 4.0 wt% the SiCp phase was not detected. It can be seen from the XRD test that the SiCp content increases, there is a tendency to increase SiCp and Mg bonds to form the Mg2Si phase, making the sample grains bigger and appear coarser. In addition, the EDX results also indicate the presence of oxygen (O2) in each sample, it is possible for the oxygen element to enter the sample during the printing and cooling process. The detection of oxygen allows the bond between aluminum and oxygen to form an Al2O3 layer which is a thin layer of aluminum protector. Apart from oxygen, there is also a percentage of carbon (C) in EDX observation. Carbon elements can be caused by SiCp which reacts with molten aluminum at high temperatures so that the Al4C3 phase is formed [1].

3.2. Corrosion Rate
Corrosion rate measurement of Al-Cu-Mg / SiCp samples with SiCp variation (3.4 wt%, 3.7 wt% and 4.0 wt%) using polarization corrosion method with Potensiostat Gamry Reference 600 using NaCl media. The results are shown in the following table.

| Sample | SiCp 3.4 wt% | SiCp 3.7 wt% | SiCp 4.0 wt% |
|--------|--------------|--------------|--------------|
| Surface Area (cm²) | 0.692 | 0.523 | 0.537 |
| Electrolyte Solution | NaCl 3.5% (b/v) | NaCl 3.5% (b/v) | NaCl 3.5% (b/v) |
| Temperature | 26.6 | 27.1 | 26.3 |
| Icorr (mA) | 1.104x10⁻³ | 1.456x10⁻³ | 0.727x10⁻³ |
| Ecorr (mV) | -971.4 | -872.8 | -735.2 |
| Density (g/cm³) | 1.49 | 1.64 | 1.69 |
| Corrosion Rate (mmpy) | 1.2828x10⁻³ | 1.1217x10⁻³ | 1.0272x10⁻³ |
| EW | 9.32 | 9.32 | 9.32 |

Figure 2 shows a graph of the potential V function of current I for sample (a) Al-Cu-Mg / SiCp (3.4 wt%) (b) Al-Cu-Mg / SiCp (3.7 wt%), (c) Al-Cu-Mg / SiCp (4.0 wt%). Corrosion test results as shown in table 1. Corrosion rates will be proportional to the corrosion current density (Icorr) and influenced by the surface area of the sample. Different sample sizes make the sample surface area vary. Based on these data the lowest corrosion rate is found in the Al-Cu-Mg sample with SiCp 4 wt%, which is equal to 1.0272 x 10⁻³ mmpy. There is a tendency, that the increasing of SiCp filler composition in the Al-Cu-Mg matrix causes a decrease in the corrosion rate [1,14,17].
When looking at phase data on XRD testing with increasing SiC, the larger SiC and Mg bonds form Mg$_2$Si. The Si element is easier to bind Mg than Oxygen (O$_2$) to form SiO$_2$. As is well known, that oxide will make the material easily corrosion. On the other hand, with increasing SiC in the sample Al-Cu-Mg matrix makes the material harder and stronger. So, it can be concluded that the increase in SiC filler into the Al-Cu-Mg matrix, will make the uncut hard and strong and more resistant to corrosive.

Figure 1. Microstructural SEM-EDX samples of Al-Cu-Mg / SiC$_p$: (a) SiC$_p$ 3.4 wt%, (b) SiC$_p$ 3.7 wt%, (c) SiC$_p$ 4.0 wt%.
4. Conclusion

Based on the results of testing the greater percent weight of SiC<sub>p</sub> into the Al-Cu-Mg matrix, the corrosion rate decreases, meaning that increasing SiC<sub>p</sub> in the Al-Cu-Mg matrix makes the Al-Cu-Mg / SiC samples tend to be more corrosive resistant. This decrease in corrosive properties is caused by SiC particles occupying the grain boundary area replacing O<sub>2</sub> which is trapped in the sample during the cooling process. As it is known that O<sub>2</sub> in this sample makes the sample corrosive.

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