

# STIR CASTING METHOD ON ALUMINA (Al<sub>2</sub>O<sub>3</sub>) COMPOSITE MATRIX WITH SiC STRENGTHEN AND MAGNESIUM (Mg) ADDITION TO MICROSTRUCTURE AND MECHANICAL PROPERTIES

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**ABSTRACT:** Aluminium is a material that can be widely used because of its lightweight, good corrosion resistance, good appearance, reliable electrical conductor, good electricity conductor, and several other advantages of this material. The development of aluminium (Al) material in aluminium matrix composite (AMC) is often applied in various fields, including automotive, industry, military, and aviation. The reinforcing particle often used in AMC is Silicon Carbide (SiC) to improve the properties of AMC. Adding magnesium (Mg) is helpful as a wetting agent for reinforcing particles and matrices. This study aims to determine the effect of adding magnesium (Mg) on the mechanical properties and microstructure of the aluminium matrix composite 1100 series reinforced with silicon carbide (SiC) using the stir casting method. The reinforcing silicon carbide (SiC) particles were added to the aluminium matrix composite (Al) by 5%. The variations in adding magnesium were 0.75%, 1.25%, and 1.75% as wetting agents. This research was carried out to determine the mechanical properties by testing the tensile strength and hardness. The hardness test results showed the highest hardness in the magnesium (Mg) 1.75% variation of 84.67 HRB and the highest tensile strength in the pure aluminium (Al) variation of 9.41 Kgf/mm<sup>2</sup>.

*Keywords:* aluminium, AMC, Mg, SiC, Stir Casting

## 1. Introduction

Aluminium is a widely used material, is lightweight, has good corrosion resistance good appearance, reliable electrical conductor, good electricity conductor, and several other advantages possessed by this material. Aluminium is widely used in several fields such as automotive, industry, affiliation, and household.

Aluminium Matrix Composite is a metal-based composite material that uses aluminium as its matrix material. The advantage of aluminium is that it combines high stiffness, high Leach resistance, and a relatively low manufacturing process. Aluminium matrix composite continues to be developed, has different variations, and has been tried with several distinct variations. The reinforcement includes continuous fibre, monofilament and multifilament, short fibre, whiskers, and particulate matter.

Another alloying element can also be done to AMC (Aluminium Matrix Composite), especially in aluminium-silicon (Al-Si) alloys. One of the elements that can be added is magnesium (Mg). Magnesium (Mg) can play a role in increasing the wettability of the aluminium composite matrix.

Magnesium (Mg) can also increase strength and hardness without decreasing flexibility.

## 2. Literature Review

Prabowo et al. [1] conducted a study by adding magnesium (Mg) and Silicon Dioxide (SiO<sub>2</sub>) as reinforcement in an aluminium matrix composite. The testing process carried out includes the density test and hardness test. The results showed that the composite's hardness value without adding magnesium (Mg) had the lowest hardness level. The addition of 2% Mg had the highest hardness value among other compositions. Overall, the resulting composite had an average composite hardness that increased after adding magnesium (Mg), but at 2.5% Mg addition, the hardness decreased.

Triyono et al. [2] conducted a study using a matrix of aluminium-remelting pistons using variations of silicon dioxide (SiO<sub>2</sub>) particle reinforcement with variations in the addition of magnesium (Mg). This study shows that adding Mg to the composite increases the material impact value. Where the lowest impact value occurs in aluminium composites that have not added magnesium (Mg), the impact price continues to increase along with the increase in the percentage of magnesium (Mg), and the highest price is

obtained from the composition of the aluminium composite matrix with 2.5% Mg addition.

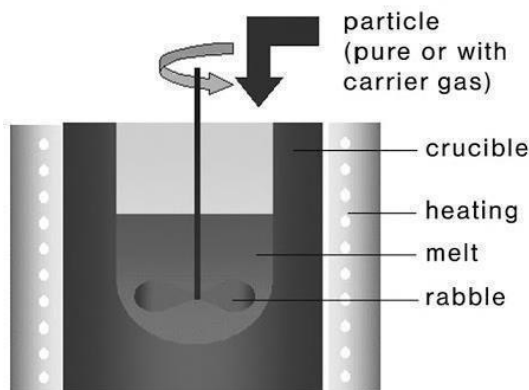
## 2.1 Composite

Composite is made from different materials with better properties than its original properties. Various metals, ceramics, and polymers produce new materials with advantages in manufacturing composite materials. Most composites are made to improve the combination of different mechanical properties such as stiffness, toughness, resistance at low temperatures, and strength at high temperatures [3].

Generally, composite materials consist of two phases: a continuous matrix that encompasses the other phases and protects, binds, and withstands and distributes the stresses the composite material receives. This covered phase is often referred to as the dispersed or reinforcement phase, which functions to withstand most of the loading received by the composite material. A composite's properties depend on the nature of the constituent phase, its number, and the geometry of the dispersed phase. The geometry of the dispersed phase in question shapes the particle and its size, distribution, and orientation [3].

## 2.2 Stir Casting

In this research, making aluminium matrix composite uses stir casting, which is made in a liquid state or by a casting process. Figure 1 illustrates the schematic of making aluminium matrix composites using stir casting.



**Figure 1** Schematic of the Composite Manufacturing Process with the Stir Casting Method [4]

Casting Process Stir Casting is a technique for making aluminium composite materials that

require a reasonably low cost. This method also has advantages over the type of material to be made. It can make composites up to 30% by volume fraction of the reinforcement with metal matrix bonds and better dispersion of the reinforcing particles due to the moving process carried out during the composite's manufacture. During the stir-casting process, mechanical stirring distributes the reinforcing phase (generally particles) to the molten aluminium.

## 3. Research Methodology

The equipment needed in the research includes:

1. Melting Furnace
  2. Stir Casting Machine
  3. Ladle
  4. Metal Mold
  5. Thermocouple
  6. Digital Scales
  10. Tensile Testing Machine
  11. Hardness Testing Machine
  12. Micro Structure Testing Equipment
  13. SEM Testing Machine
- Materials needed in this research:

Aluminium is needed for casting each variation. The weight of aluminium is based on the volume of castings from metal moulds that have been made. The mould has dimensions of 20cm × 4cm × 4cm, so:

Castings Volume = 320 cm<sup>3</sup> Aluminium weight required

$$= \text{density of aluminium} \times \text{volume of castings} \\ = 2.71 \text{ gr / cm}^3 \times 320 \text{ cm}^3 = 867.2 \text{ gr}$$

Because once Casting is done four times, the total weight of aluminium is:

$$\text{Overall aluminium weight} \\ = 867.2 \text{ gr} \times 4 = 3468.8 \text{ gr}$$

To anticipate the lack of liquid aluminium to fill the entire mould, the weight of aluminium is increased to 4000 grams for each variation.

To get the required weight of the reinforcing particles and alloying elements, the formula used is: % mass fraction × total weight Al = ... (gr)

### 1. Aluminium Series 1xxx

Aluminium is a light metal with good corrosion resistance, good electrical conductivity, and other valuable properties as a metal property. In addition, its mechanical strength is significantly increased with the addition of Cu, Mg, Si, Mn, Zn, and Ni, individually or in combination. It also provides other beneficial

properties such as corrosion resistance, wear resistance, and low expansion coefficient. This material is used in a wide field not only for household appliances but also for material purposes for aircraft, cars, ships, and construction [5].

## 2. Silicon Carbide (SiC)

SiC (Silicon Carbide) is a crystalline compound with mechanical properties, the highest hardness, and a melting point of around 2837°C. SiC has the highest purity and atomic weight of 40.1 grams, 70.04% Si, and 39.06% C. Silicon Carbide (SiC) is a non-oxide ceramic material made with silica in an electric furnace. The simplest polytype of silicon carbide is the diamond structure.

## 3. Magnesium

Magnesium is a reactive element whose function is to increase the ceramic particles' wetting ability to the aluminium matrix so that it can produce a strong bond. This magnesium alloy element can improve the aluminium matrix by forming a temporary layer between the reinforcing particles and the molten aluminium. This layer produces a low wetting angle, can reduce the surface tension of molten aluminium, and coats the reinforcing particles with the same material between particles and liquid aluminium [4].

### Stir Casting Melting Process

- After weighing the materials is done, the steps for the stir-casting melting process are as follows:
- Melt aluminium in a melting furnace until it reaches a perfect liquid state (700°C).
- Heating SiC particles to a temperature of 500°C and metal moulds are also heated to 100°C.
- Turn on the stir casting tool at 500 rpm, and then Mg powder is added to liquid Al.
- Entering the heated particles and stirring for 5 minutes.
- Increase the temperature of the melting furnace again, then pour it at a temperature of 800°C.
- Cooling is done using water media.

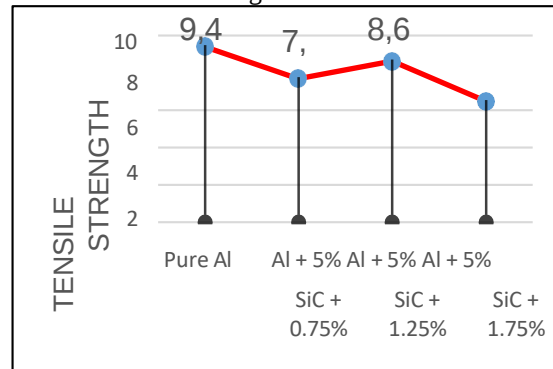
### Testing

Hardness testing uses the Rockwell Hardness Tester with a B scale indenter (Ball Ø 1/16 "). From the results of this test, it can be seen that the hardness value of AMC material has. Tensile testing is done by slowly applying a tensile load to the test rod until it breaks. Creep limits, tensile strength, elongation, cross-sectional area

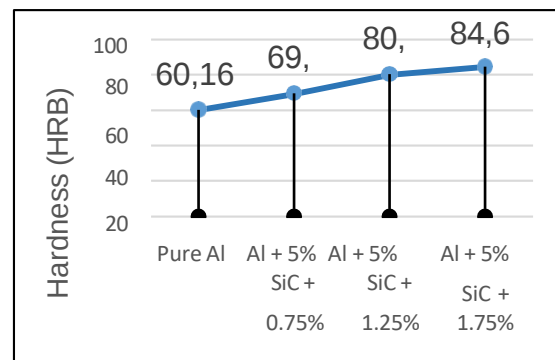
reduction, etc., are measured in this test. Tensile testing in research using the ASTM E8M testing standard strain and stress values of the AMC material will be obtained from this test to determine the microstructure's effect due to the addition of reinforcing particles, precise observation of the reinforcing particles' microstructure and distribution can be observed by conducting a Scanning Electron Microscope (SEM) test on AMC material.

## 4. Result and Discussion

### 1. Hardness Testing



**Figure 2** The relationship between the addition of Mg and the tensile strength



**Figure 3** The effect of adding Mg to the hardness

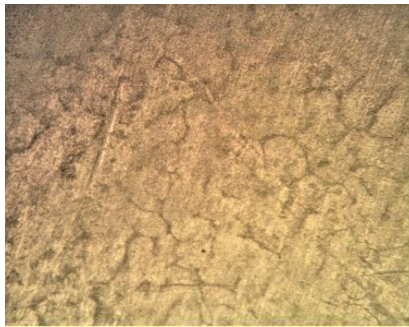
Figure 2 shows that the increase in the hardness value of pure aluminium to Al- SiC composite aluminium occurs due to the addition of SiC (Silicon Carbide), which has mechanical properties with high hardness. Consequently, the process of spreading SiC particles on the 1100 series aluminium composite matrix occurs. The increase in hardness and the increase in Mg (magnesium) occur. Magnesium (Mg) is an element that can increase the strength and hardness of a material; besides that, Mg also acts as a material that increases the wettability between the composite matrix and the reinforcing material. The more magnesium (Mg), the

wettability between the SiC and aluminium reinforcing particles will increase, and the bond between the matrix and the reinforcement will improve. Therefore, the silicon carbide (SiC) bound to aluminium (Al) is getting bigger and spread evenly, indicated by increasing composite hardness value.

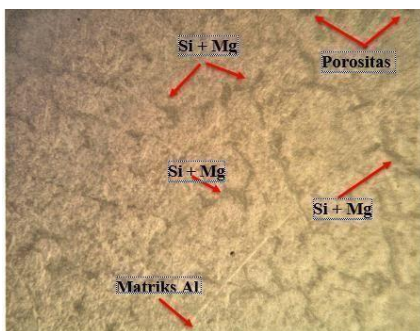
## 2. Tensile Testing

From Figure 2, it can be seen that there is a decrease in Al - SiC composites compared to the pure material, namely the Al 1100 series. This decrease occurs because of the porosity of the Al - SiC composite castings; porosity occurs due to the stir casting method. The stir-casting process causes a vortex that causes air on the surface of the liquid metal or air from outside to be sucked into the molten metal. A decrease in the tensile strength value can be caused by the reinforcing fraction clumping on the molten metal surface due to the significant density difference with the liquid metal, resulting in uneven mixing.

## 3. Observation of Micro Structure

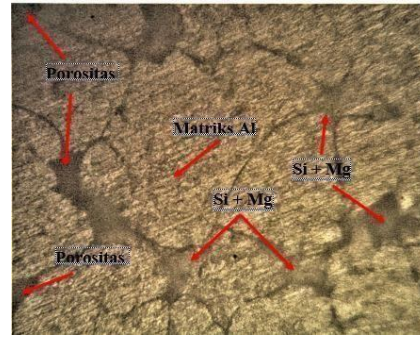


**Figure 4** Microstructure of pure Al at 250x magnification

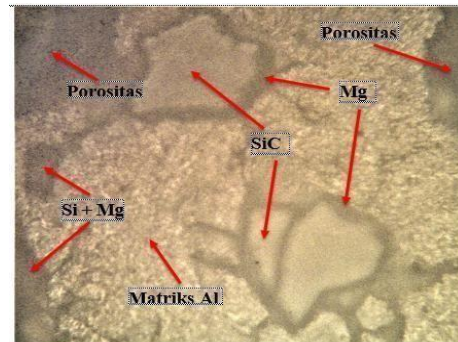


**Figure 5** Microstructure of Al + 5% SiC + 0.75% Mg at 250x magnification

From Figures 4-7, the microstructure shows that the greater the addition of magnesium (Mg), the more reinforcing particles are bound to the aluminium matrix.



**Figure 6** Microstructure of Al + 5% SiC + 1.25% Mg at 250x magnification

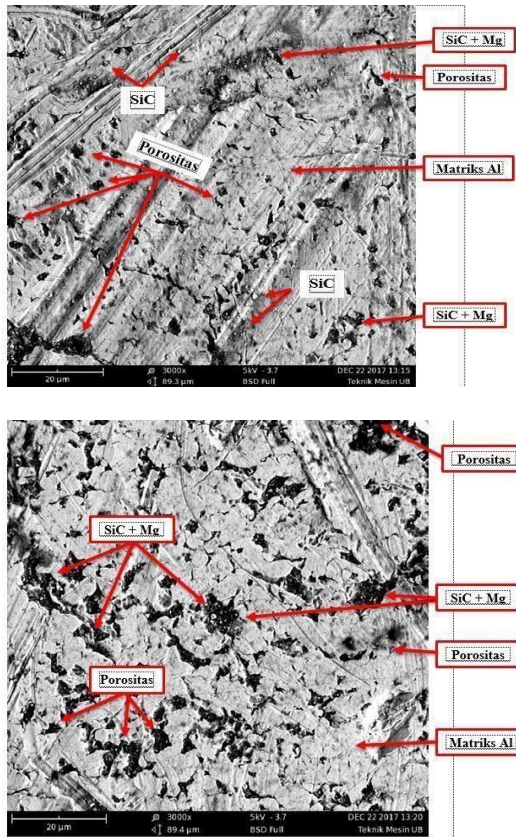


**Figure 7** Microstructure of Al + 5% SiC + 1.75% Mg 250x magnification

If more and more reinforcing elements are attached to the aluminium (Al) matrix, it can increase the Al - SiC composite's hardness value. The Mg element as wettability in composites is beneficial and can make the reinforcing particle and matrix bonds better to increase the composite's strength and hardness [2]. In the image of the microstructure above. It can also be seen that the Al - SiC composites cast by the stir casting method experienced porosity. The porosity and the holes from the silicon carbide (SiC) attachment were primarily found in 6 specimens with a magnesium (Mg) percentage of 1.75%. Increasing the rate of reinforcement causes the accumulated silicon carbide (SiC) to be significant.

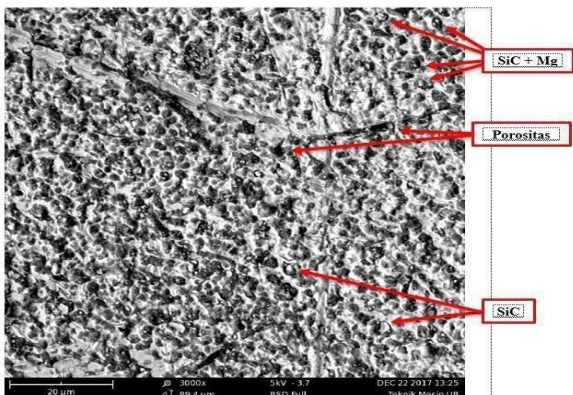
## 5. SEM Observation

Figures 8 show the SEM test results. From the SEM observations in Figures 4-7, it can be seen that the greater the addition of magnesium (Mg), the more reinforcing particles are bound to the aluminium matrix. In the Mg addition of 0.75%,



**Figure 8** SEM observations of Al + 5% SiC + 0.75% Mg at 3000X magnification

magnesium (Mg) distribution was less homogeneous and uneven. Along with the addition of magnesium (Mg), the distribution of silicon carbide (SiC) particles is getting even and firmly bonded to the aluminium composite matrix (Al). Magnesium (Mg) as wettability affects the distribution of the reinforcing silicon carbide (SiC) particles so that the amplifying particles are evenly distributed, and the grain size is getting smaller, which can be proven by the results of SEM observations [6].



**Figure 9** SEM observations of Al + 5% SiC + 1.25% Mg at 3000X magnification

### 3. Conclusions

From the results of the research, the following conclusions were obtained:

1. The hardness test results of pure aluminium (Al) before being given the reinforcing particles of silicon carbide (SiC) and magnesium (Mg) were 60,167 HRB. After aluminium was added to the reinforcing particles of silicon carbide (SiC) and magnesium (Mg), an increase occurred with the addition of magnesium (Mg). The increase in Al - SiC composites' hardness value was 40% compared to the hardness of pure aluminium (Al).
2. The results of the tensile strength test for pure aluminium (Al) have a tensile strength of 9.41% kgf / mm<sup>2</sup>, and with the addition of magnesium (Mg) to the Al - SiC composite, the tensile strength has decreased by 31%.
3. The microstructure and SEM observations showed that the greater the magnesium (Mg) addition, the more silicon carbide (SiC) reinforcing particles bound to the aluminium matrix. The microstructure and SEM also show the porosity of the Casting with the stir casting method.

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