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by Sulardjaka Sulardjaka

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Investigation of Mechanical Properties of Al7Si/SiC and Al7SiMg/SiC Composites Produced by Semi Solid Stir Casting Technique

Sulardjaka [1*], Sri *Nugroho* [2], Suyanto [3], Deni Fajar *Fitriana*

[1] Mechanical Engineering Department, Diponegoro University, Semarang, Indonesia
Jl. Prof. Soedharto, Tembalang, Semarang, Indonesia, Phone: 024-7460059.

Abstract. Mechanical characteristic of silicon carbide particle reinforced aluminum matrix composites produced by semi solid stir casting technique was investigated. Al7Si and Al7SiMg were used as metal matrix. High purity silicon carbida with average particle size mesh 400 was used as reinforcement particle. Aluminum matrix composites with variation of SiC: 5 %, 7.5 % and 10 % wt were manufactured by the semi solid stir casting technique. Stiring process was performed by 45 ° degree carbide impeller at rotation of 600 rpm and temperature of 570 °C for 15 minutes. Characteritation of composites speciment were: microscopic examination, density, hardness, tensile and impact test. Hardness and density were tested randomly at top, midlle and bottom of composites product. Based on distribution of density, distribution of hardness and SEM photomicrograph, it can be concluded that semisolid stir casting produces the uniform distribution of particles in the matrix alloy. The results also indicate that introducing SiC reinforcement in aluminum matrix increases the hardness of Al7Si composite and Al7SiMg composite. Calculated porosities increases with increasing wt % of SiC reinforcements in composite. The addition of 1 % Mg also increases the hardness of composites, reduces porosities of composite and enhances the mechanical properties of composites.

1. Introduction

The aim in designing metal matrix composite materials is to combine the desirable attributes of metal and reinfocement materials. The addition of high strength, high modulus refractory particles to a ductile metal matrix produces a material whose mechanical properties are intermediate between the matrix alloy and particle reinforcement [1]. Aluminum metal matrix composites (AMCs) have wide application in aerospace, defence and selected automotive applications such as high performance racing applications. These properties include improved strength, high elastic modulus, hardness, wear resistance, attractive thermal and electrical characteristics [2-5].
Many techniques have been developed for producing particulate reinforced aluminum metal matrix composite, such as powder metallurgy, spray decomposition, liquid metal

*Corresponding author: sulardjaka@undip.ac.id

infiltration, squeeze casting and stir casting [6, 7]. Among these processing techniques, stir casting is one of the methods which is accepted for the production of large quantity commercially practised. The most common problem regarding to production of AMCs in casting routes, including stir casting are porosity and how to achieve the uniform distribution of reinforcement within the matrix [8].

Preparation of low cost SiC particle reinforced MMCs, is very difficult to be prepared due to difficult dispersion SiC particle [9]. In order to produce homogeneously reinforced MMC components, the method chosen for particle incorporation within the matrix becomes important. Some techniques for introducing and mixing the particles have inherent disadvantages. To fabricate AMCs with good mechanical properties, other important factors that need to be considered include the effect of poor reinforcement wettability particulate in the matrix and the propensity on the introduction of porosity during the particle incorporation phase [10]. The wettability of ceramics particle with liquid aluminium alloys is generally poor. The addition of alloying elements can modify the matrix metal alloy by producing a transient layer between the particles and the liquid matrix. Ca and especially Mg were very efficient in increasing the incorporation of ceramic particles into the molten aluminum [11]. Another method to improve the wettability and the distribution of SiC particles are by stirring process in semisolid state rather than in fully liquid state [12, 13]. The aim of the present study is to investigate mechanical characteristics of aluminum Al7Si/SiC and Al7Si1Mg/SiC composites produced by semi solid stir casting methods.

2. Materials and Methods

Aluminum die casting (ADC 11) ingot was used as the matrix. **Table 1** shows the chemical composition of aluminum used in the present study. Micron-sized SiC particles with average particle size mesh of 400 and purity of 99.9% was supplied as the reinforcement of metal matrix composite. Master alloy magnesium was used as alloying element.

Table.1. Chemical composition of ADC 11 ingot

	Al	Si		Fe	Mn	Mg	others
%wt	92.39	7.26		0.147	0.008	0.07	--

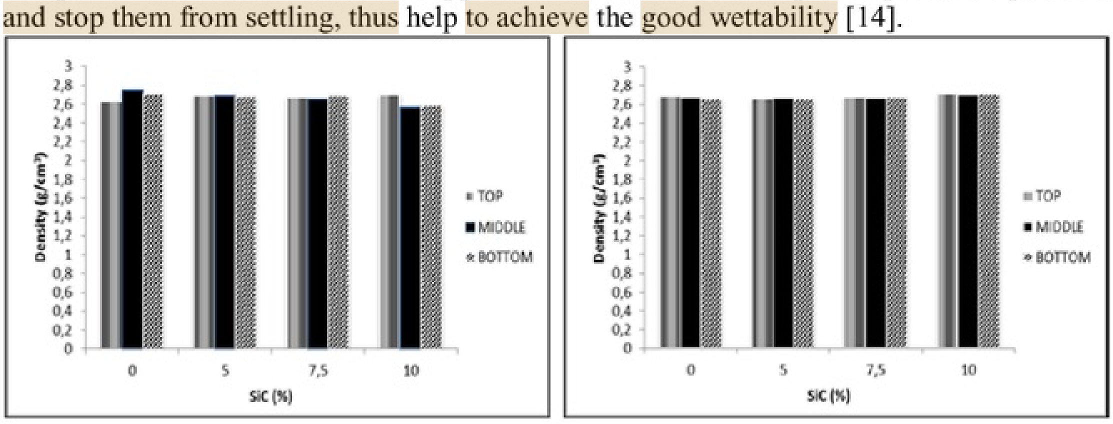
Aluminium die casting (ADC 11) was melted in controllable temperature electric furnace. Argon gas was flowed into the furnace to prevent oxidation of aluminum. In this process, approximately, ADC 11 ingot of 850 g was charged into the crucible heated up to 750 °C for melting. To obtain Al7SiMg matrix alloy, master alloy magnesium and aluminium were melted together in crucible furnace.

The SiC addition is carried out between the liquidus and solidus temperatures. SiC particles were preheated until temperature of 250 °C. The preheated SiC particles are added to semi solid molten aluminum at temperature of 570 °C. The semi solid alloy is mechanically stirred using a ceramics impeller driven by an electric motor at 600 rpm for 15 minute. Then the temperature was raised up to 750 °C and the molten product was poured into the low carbon steel mold. This process produces 90 mm x 125 mm x 10 mm square aluminum matrix composite block billets.

Density of the composites was tested by the Archimedes principle. Theoretical density of composites was calculated using the rule of mixture according to the mass fraction of the SiC particles. Hardness of AMCs product was tested by Rockwell B hardness test based on ASTM E18-11. The density and hardness tests were done randomly at the top, middle and bottom of the composite casted products. Microstructural analysis was performed using SEM (JEOL-JSM 5600LV) on etched HF solution polished specimens. The tensile tests were conducted according to ASTM E 8M-04 standard. Impact tests of composites products were tested using Charpy Impact Test Machine.

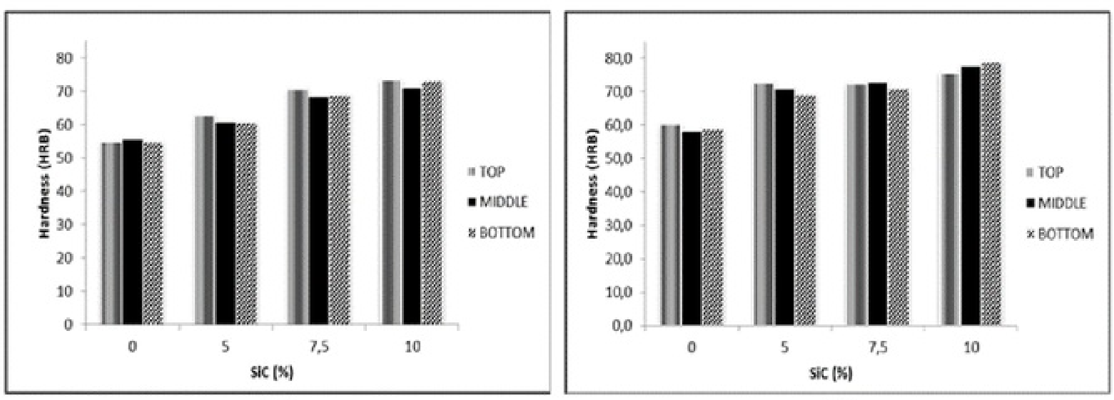
3. Results and Discusions

The distribution of density of composites products are shown in **Fig. 1.a** and **Fig.1.b.** It can be pointed that there are no significant differenceses of density at bottom, midlle and top of composite plate. **Fig. 2.a.** and **2.b.** shows hardness distribution of composites products. Based on hardness and density observations, it can be concluded that semi solid stir cast produces the composite with homogen distribution of SiC particle. Stiring at semi solid state causes SiC particles are mechanically entrapped. This condition can help to trap the SiC particles and stop them from settling, thus help to achieve the good wettability [14].



(a) (b)

Fig.1. Density distribution of AMCs reinforced SiC particle. (a) Al7SiSiC (b) Al7Si1MgSiC



(a) (b)

Fig.2. Hardness distribution of AMCs reinforced SiC particle (a) Al7SiSiC (b) Al7Si1MgSiC

The effect of % wt of SiC on hardness of Al7Si composite and Al7SiMg composites are shown in **Fig. 3**. The hardness of Al7Si composites with 5 %, 7.5 % and 10 % wt SiC are HRB 61, HRB 69 and HRB 72 respectively. The hardness of Al7SiMg composites with 5 %, 7.5 % and 10 % wt SiC are HRB 71, HRB 75 and HRB 80, respectively.The rise of % wt SiC increases the hardness of both Al7Si composite and Al7SiMg composite.

Tensile strength and elongation of composites are shown in **Fig. 4**. It is shows that tensile strength with 5 % wt SiC is higher than aluminum without reinforced particle. The increase in tensile strength of composites is caused by presence of the hard and higher modulus SiC particles embedded in the aluminum matrix. SiC particle acts as a barrier to resist plastic flow when the composite is subjected to strain from an applied load [15]. The rise of % wt from 5 % wt to 10 % wt decreases the tensile strength and elongation of composites. The weakening factors of tensile strength of composite might be responsible for the included particles clusters and porosity [16]. In **Fig. 5**. shows that compare to aluminium monolitic, there isn't significant increasing of porosity of 5% wt SiC composite.

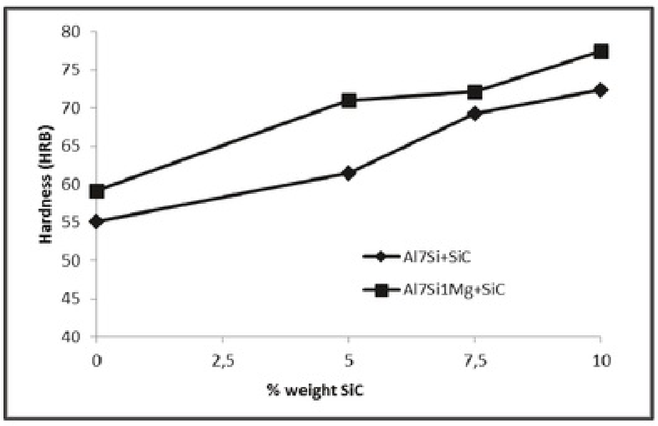


Fig. 3. The hardness of Al7Si and Al7SiMg composites

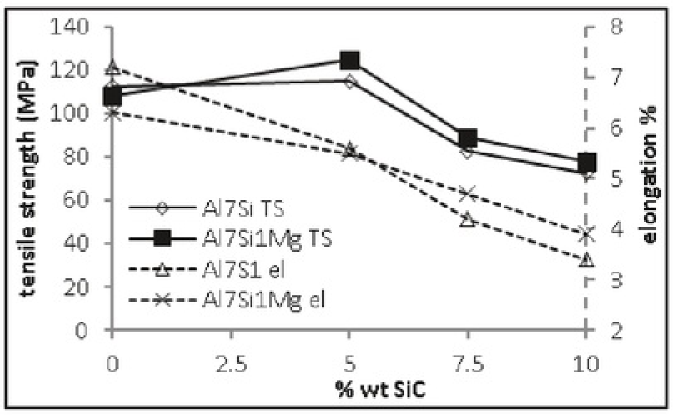


Fig. 4. The tensile strength and elongation of Al7Si and Al7SiMg composites.

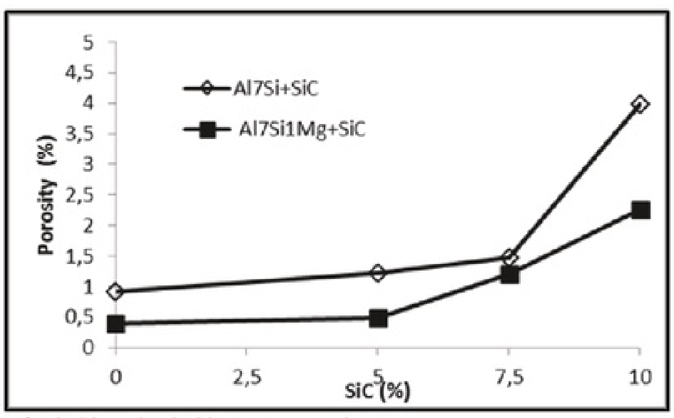
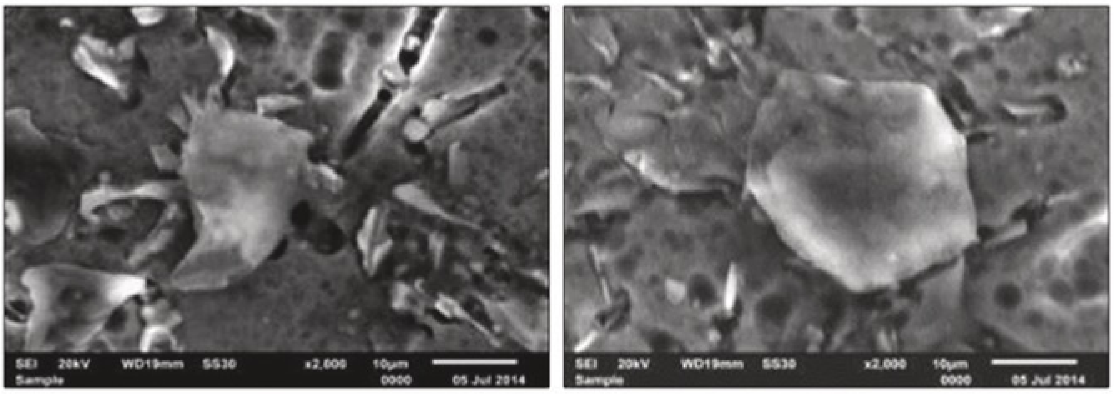


Fig. 5. The porosity of Al7Si and Al7SiMg composites



(a) (b)

Fig. 6. (a) Scanning Electron Micrograph Al7Si and SiC particle (b) Scanning Electron Micrograph Al7SiMg and SiC particle

The addition of 1 % Mg increases the hardness and tensile strength of composites. It is observed that the tensile strength of Al7SiMg/SiC is higher than Al7Si/SiC. The increase in the tensile strength of Al7SiMg/SiC can be attributed that Mg increases the bonded SiC reinforcements in Al matrix. Previous authors reported that Mg is known to improve wettablity by reducing the surface tension of the liquid melts [14, 17,18]. **Fig. 5** shows that Mg also decreases the porosity of composites. Mg is also promoting the chemical reaction at the solid liquid interface as shown in **Fig. 6 (a)** and **Fig. 6(b)**. Mg causes less void formation between matrix and particle reinforcements interface which indicates a better matrix–reinforcement interfacial bonding and increasing the impact strength of Al7SiMg/SiC. **Fig. 6.a** shows that some void interfaces formed betwen matrix and SiC particle are found. Porosity causes the stress concentration areas in the composite that leads to the reduce in the tensile and impact strength [18]. The impact strength of composite is shown in **Fig. 7**, and it can be observed that the impact stregth of Al7SiMg/SiC composite is higher than Al7SiMg.

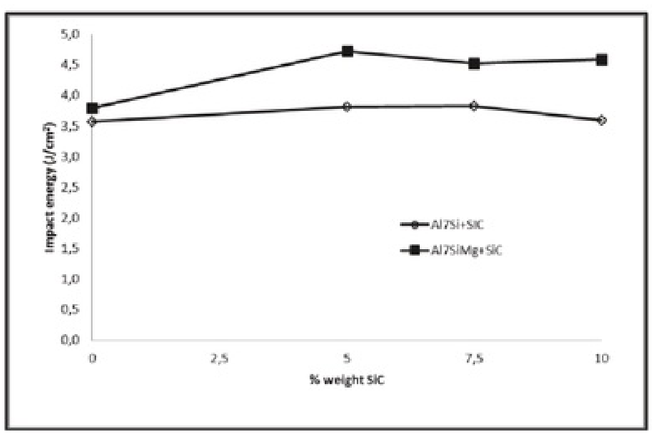


Fig. 7. The impact strength of Al7Si and Al7SiMg composites

4. Conclusions

This study demonstrates the semi solid stir casting technique to enhance the mechanical properties of Al7Si/SiC and Al7SiMg/SiC composites. The following results could be drawn from this study:

1. Semi solid stir casting succesfully produces the homogeneous distribution of SiC particle on aluminum matrix.

2. The addition 1 % Mg decreases the porosity and improves: hardness, tensile strength and impact toughness of the composites.
3. Increasing % wt of SiC from 5 % to 10 % wt will decrease the tensile strength and elongation of composites.

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