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Effect Composition of SiC_p and TiB to the Mechanical Properties of Composite Al7Si-Mg-SiC_p by the Method of Semi Solid Stir Casting

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Abstract. Recently, studies on Aluminum Matrix Composite (AMC) were growing rapidly. AMC reinforced with SiC_p particles in the semi solid stir casting method was the most simple way. In particular, the purpose of the present study was to investigate the effect composition of SiC_p and TiB to the mechanical properties of the composites Al7Si-Mg-SiC_p and Al7Si-Mg-TiB-SiC_p. The composites used were Al7Si as the matrix and SiC_p as the reinforcement (10, 15, 20 wt%). The casting method used on the study was the semi solid stir casting. The matrix was melted at the temperature of 800 °C. Then, the stirring process started at 590 °C with the speed of 500 rpm for 180 seconds. The composites was heated again until the pouring temperature was at 750 °C. The results of the present study indicated to be successful in which SiC_p particles dispersed uniformly in the matrix composites. Further, the hardness value and porosity of the composites Al7Si-Mg-SiC_p and Al7Si-Mg-TiB-SiC_p increased along with the addition of TiB. Besides, the hardness value increased in the average of 10.5% at the variation of 20% SiC_p. Whereas, the porosity value increased in the average of 54.3% at the variation of 20% SiC_p.

INTRODUCTION

Aluminum Matrix Composites (AMC) is a type of composite material metal which has a great potential to be developed. In this case, aluminium plays a role as the matrix; whereas, SiC_p powder as the reinforcement. It is because of the combination of its good properties. AMC widely applied in the automotive industries, aerospace, and defense. The Making of the AMC reinforced SiC_p to combine the mechanical properties between matrix and reinforcement [1]. Along with the addition of TiB element, it could increase the hardness value. Aluminium alloy (e.g. A356) has some advantages in its properties such as light (density 2.7 g/cm3) and corrosion-resistant. However, for certain applications are required high-level of strength and hardness. Besides, aluminium has mechanical properties that are less supportive, because it has low hardness, strength, and rigidity; ie hardness HB 60 [13]. The specification of SiC_p was it had the density of 3.2 g/cm3, yields strength of 600 MPa, hardness of Knop 2480 (HB 2170), and the elastic modulus of 400 GPa [6].

In the previous study in which AlSi7Mg2 reinforced with SiC_p (5-15 wt%), the results obtained were hardness 98 HB at 15% SiC_p increased by 48%; and the tensile strength of 10% SiC_p was 280 MPa [4]. The Al6062 matrix with the variations of SiC_p (5, 10, 15, 20 wt%) obtained the highest hardness results in 20% SiC_p as much as 83 HRB [10]. The A356 alloy and the Graphite reinforced with SiC_p (0-9 wt%) attained a maximum increase of hardness

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results in 9% SiC_p as much as 144VHN [11]. The study of AlTiC and AlTiB with variations of 0.2%, 0.5%, 1% obtained the result that because of the addition of 1% TiB, the grain size got smaller [5]. The result obtained from the Al7178 matrix with TiB variations of 1%, 2%, 3%, 4% was due to the addition of TiB between 1% to 4%, the grain significantly decreased; that was 140 µm became 55 µm [8]. The AlTiB master alloy with variations of 0.03% to 0.15% with the smallest grain of 50 µm was achieved at 0.13% TiB [9]. The addition of TiB element is used as the grain refinement. It was because that particular property could increase the hardness and the grain refinement. By the existence of the element of TiB, the propagation of dislocation which may occur would be smaller. With the addition of Mg element, it may increase the liquid wettability of the A359 matrix to particle SiC_p. Nevertheless, the addition of Mg element that exceeded 1% had the potential to increase the viscosity and reduce the spread of particle SiC_p [3]. The percentage addition of SiC_p would improve the mechanical properties such as hardness and toughness. The gas trapped during the mixing process would cause porosity which may trigger a reduction in force [7].

In the study, the stirring in the molten condition may cause the reinforcing particles, in this case, SiC_p, float on the surface of liquid matrix. Besides, the semi-solid condition could help u[illegible]ring the matrix and reinforcement. However, it must be heated until the casting temperature [2,12]. The purpose of the present study was to investigate the effect composition of SiC_p and TiB to the mechanical properties of the composites Al7Si-Mg-SiC_p and Al7Si-Mg-TiB-SiC_p.

RESEARCH METHODS

The present study developed the hardness levels in aluminium alloy (Al-7Si) reinforced with SiC_p by adding 1% Mg to improve wettability, and 1.5% TiB as the grain refinement to obtain hardness values with variations of SiC_p (10, 15, 20 wt%). The following was Table 1 showing the chemical composition of the material.

This process is first conducted to prepare the material to be melted is Al7Si (ingot), Mg (ingot) and TiB. These materials are a small cut in accordance with the mixing weight ratio. This was done to simplify the process of mixing the composition settings. Each ingredient is weighed to obtain mass composition according to the variation. Variations in every material weighing results are shown in Table 2.v

The first stage of the casting mass percentage SiCp (10, 15, 20 wt%) was Al7Si-1Mg. Then, the second stage of the casting mass percentage SiCp (10, 15, 20 wt%) was Al7Si-1Mg-1.5TiB. Here was Fig. 1 which showed the electric furnaces stir casting.

TABLE 1. Chemical composition of materials

Materials	Chemical composition (%)							
	Al	Si/SiC_p	Fe	Ti	B	Mg	Mn	Other
Al7Si / A356 (ingot)	92.39	7.26	0.147	-	-	0.07	0.008	0.125
Mg (ingot)	0.022	0.013	0.003	-	-	99.93	0.012	0.02
SiC_p (powder)	0.03	98.6	0.1	-	-	0.03	-	1.24
TiB	93	0.16	0.16	5.00	0.98	-	-	0.05

In the process of melt into the first electric furnace, Al7Si was heated to 800 oC to achieve the perfect liquid state. Whereas, SiCp was heated beforehand at 400 oC in the oven. Then, the materials Mg-TiB+SiCp was added into the electric furnace. After that, the temperature inside the electric furnace was lowered to 590 oC to attain the semi-solid condition. Furthermore, thoroughly stirred by a mechanical stirrer. The stirrer rotational speed was at 500 rpm and the stirring time was 180 seconds long. Then, it must be heated again until the pouring temperature was at 750 oC. Besides, the metal mold was heated to 300 oC. The mold results were cooled at the room temperature. After that, the specimen material was cut to fit the specimen. Here was Fig. 2 flow process stages semi-solid stir casting, is shown in graph. Figure 3 showed an illustration of the casting results.

TABLE 2. Variations in the composition of foundry

Composition	Al7Si (gram)	Mg (gram)	TiB (gram)	SiC_p (gram)	Total (gram)
Al7Si-1Mg	990	10	-	-	1000
Al7Si-1Mg-1.5TiB	975	10	15	-	1000
Al7Si-1Mg+ SiC_p 10%	890	10	-	100	1000
Al7Si-1Mg+ SiC_p 15%	840	10	-	150	1000
Al7Si-1Mg+ SiC_p 20%	790	10	-	200	1000
Al7Si-1Mg-1.5TiB+ SiC_p 10%	875	10	15	100	1000
Al7Si-1Mg-1.5TiB+ SiC_p 15%	825	10	15	150	1000
Al7Si-1Mg-1.5TiB+ SiC_p 20%	775	10	15	200	1000

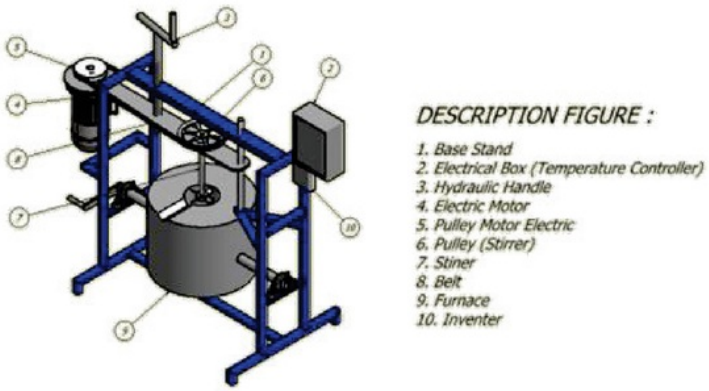


FIGURE 1. Electric furnaces stir casting

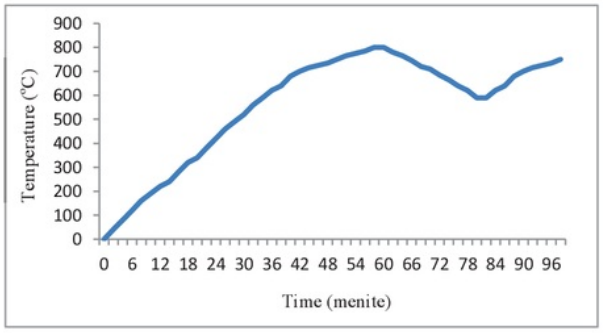


FIGURE 2. Time vs temperature semi solid stir casting process

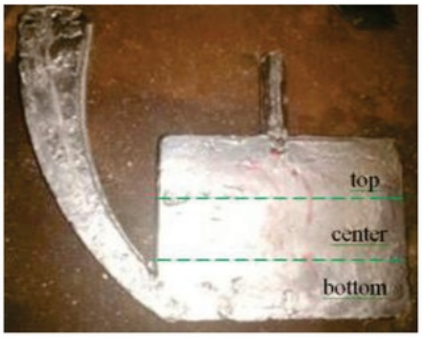


FIGURE 3. Casting results

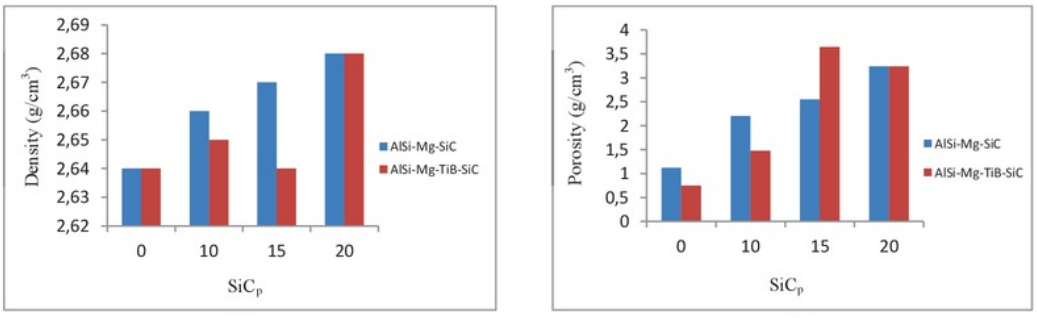
RESULTS AND DISCUSSIONS

Density and Porosity

The results of testing the density and the porosity calculations of the composites Al7Si-Mg-SiC_p and Al7Si-Mg-TiB-SiC_p were shown in Table 3. The density and porosity graphs of casting results with the percentage of SiCp were shown in Figure 4.

TABLE 3. Test results density and porosity calculations

Materials	SiC_p (wt%)	ρ_{actual} (g/cm^3)	$\rho_{theoretic}$ (g/cm^3)	Porosity (%)
Al7Si-Mg+SiC_p	0	2.64	2.67	1.12
	10	2.66	2.72	2.20
	15	2.67	2.74	2.55
	20	2.68	2.77	3.24
Al7Si-Mg-TiB+SiC_p	0	2.64	2.66	0.75
	10	2.65	2.69	1.48
	15	2.64	2.74	3.64
	20	2.68	2.77	3.24



(a) (b)

FIGURE 4. Graph (a) density, (b) the level of porosity composite

The graphs above showed that the density of the composite Al7Si-Mg-SiC_p experienced an average increase of 1.2%. Whereas, the composite Al7Si-Mg-TiB-SiC_p underwent a decrease in the variation of 15% SiC_p; then, an increase of 1.4% on the variation of 20% SiC_p. For the composite porosity Al7Si-Mg-SiC_p, it experienced an average increase of 28%. Meanwhile, the composite Al7Si-Mg-TiB-SiC_p went through an increase in the variation of 15% SiC_p, and then, underwent a decrease of 10.9% in the variation of 20% SiC_p. During the process of stir casting, porosity might potentially occur. In particular, porosity occurred due to a chemical reaction between the matrix and reinforcing particles. In this case, it caused the gas trapped during the mixing process. Consequently, the more the number of SiC_p was, the more the gas reaction would be; thus, porosity might increase.

Hardness Test

The hardness test of Rockwell B (HRB) which was based on the standard ASTM E18-11 may produce the data of hardness material shown in Table 4 as follows. The relationship graph between the harness of casting results and the SiCp percentage was shown in Figure 5.

TABLE 4. Hardness rockwell B test (HRB)

Materials	SiC_p (wt%)	Hardness (HRB)
Al7Si-Mg+SiC_p	0	56
	10	73.4
	15	82.2
	20	88.3
Al7Si-Mg-TiB+SiC_p	0	68.2
	10	79.6
	15	87.3
	20	97.6

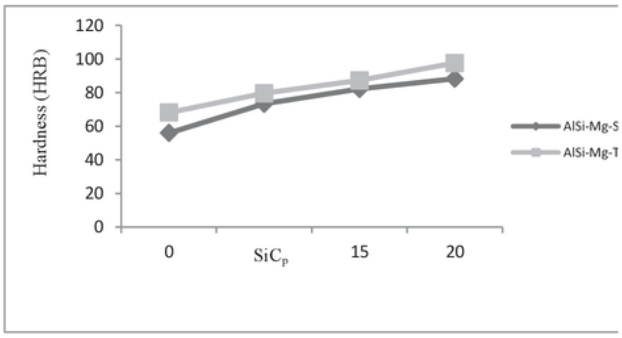


FIGURE 5. The graph composite hardness test

The graph above indicated that the composite hardness may increase along with the increasing percentage of SiC_p addition. In this case, the highest level of hardness could reach 97.6 HRB at Al7Si-Mg-TiB-SiC_p with the variation of 20% and the average value of 21.8%. In the composite Al7Si-Mg-SiC_p, the hardness could reach 88.3 HRB at the variation of 20% and the average value of 33.7%. Therefore, along with the addition of TiB element, it could increase the hardness value which may reach 10.5% because TiB elements act as grain refinement structure.

Micro Structure

The structure micro testing by using Olympus, an optical microscope with a magnification Al7Si-Mg of 100X, produced photos structure micro of Al7Si-Mg- SiC_p and Al7Si-Mg-TiB-SiC_p in Figure 6 and 7. Figure 6 The composite Al7Si-Mg-SiCp looked gray with irregular round beads; that was Si. Besides, Mg was seen around the SiCp particles, and it served to improve the wettability matrix to SiCp. Whereas, a part of matrix that was black were increasingly fine grain boundaries. Then, Fig. 7 indicated that the composite Al7Si-Mg-TiB-SiCp with black color was on the fine grain boundaries. It shows that TiB produce grains on that composite. The more SiCp dispersed, the harder it may become.

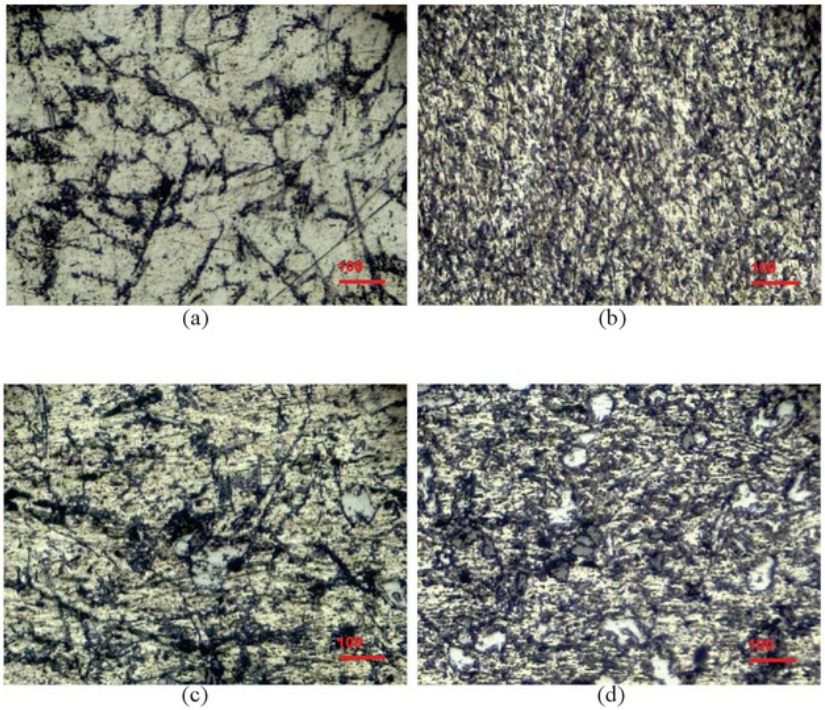
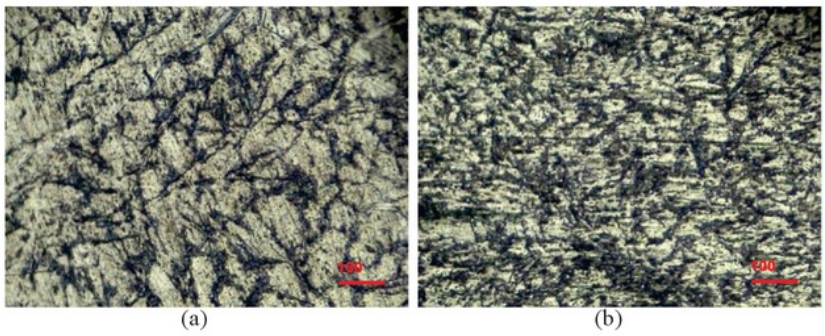
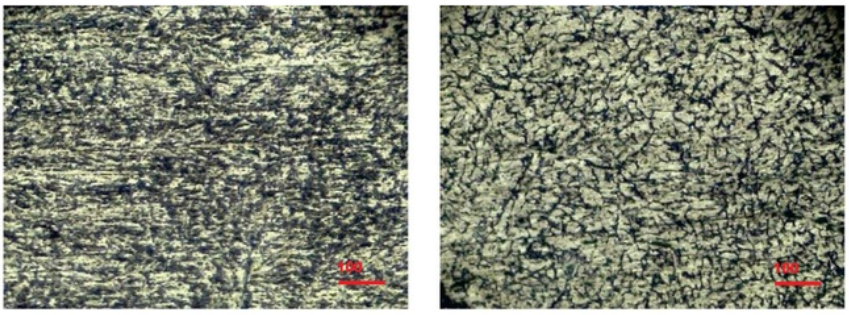


FIGURE 6. Micro composite AlSi-Mg-SiC_p (a) 0% SiC_p (b) 10% SiC_p (c) 15% SiC_p (d) 20% SiC_p



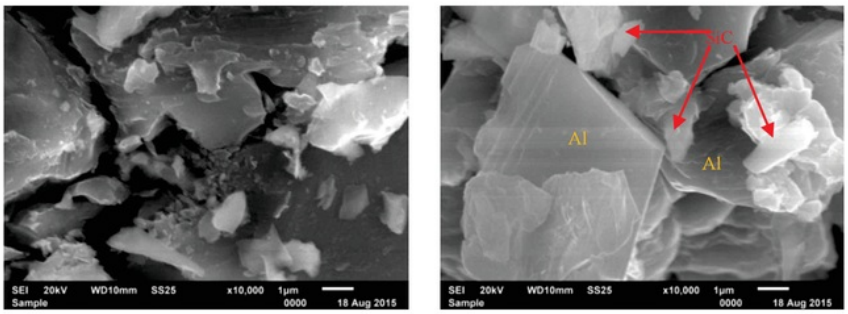


(c) (d)

FIGURE 7. Micro composite AlSi-Mg-TiB-SiC_p (a) 0% SiC_p (b) 10% SiC_p (c) 15% SiC_p (d) 20% SiC_p

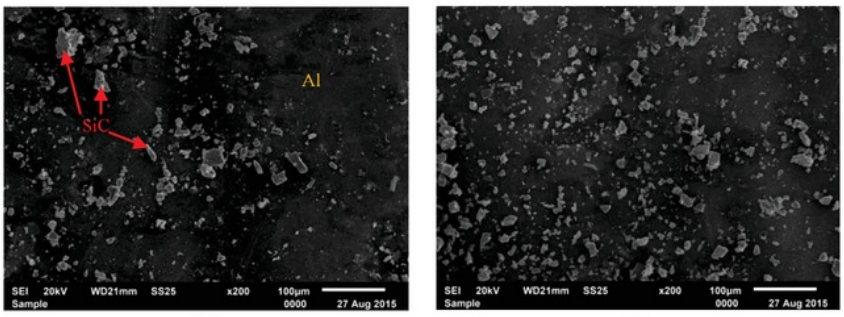
The Results of the Morphology Test

The morphology image with the magnification of 10.000X and 200X produced the micro-photos of Al7Si-Mg-SiC_p and AlSi-Mg-TiB-SiC_p in Fig. 8 and 9.



(a) (b)

FIGURE 8. The morphology of composites (a) AlSi-Mg-SiC_p 20% SiC_p (b) AlSi-Mg-TiB-SiC_p 20% SiC_p



(a) (b)

FIGURE 9. SEM of composite (a) AlSi-Mg-SiC_p 20% SiC_p (b) AlSi-Mg-TiB-SiC_p 20% SiC_p

Figure 8 and 9 the morphology of the composites AlSi-Mg-SiC_p and AlSi-Mg-TiB-SiC_p between reinforcing particles and matrix could be fused. In the composite AlSi-Mg-SiC_p, there were SiC_p particles surrounding the Al7Si matrix that was mutually binding. Whereas, the composite AlSi-Mg-TiB-SiC_p, was seen between SiC_p and matrix Al7Si in which they could mix well. Then, with the addition of TiB, it may cause changes in the particle shape to become smoother and spread evenly.

CONCLUSION

The results obtained in this study to test density and porosity, hardness, as well as the microstructure came to several conclusions. The hardness with the matrix of the aluminium composite would increase along with the increasing levels of SiC_p. With the addition of 1% Mg and 1.5% TiB, the aluminium matrix may be capable of improving the wettability of SiC_p particles, as well as making the grain become smooth along with the increase concomitant of TiB and an increase in hardness. The value of hardness was increased in average 10.5% at variation of 20% SiC_p. The value of porosity was increased in average 54.3% at variation of 20% SiC_p. The homogeneous dispersion of SiC_p particles in an aluminium matrix could be achieved by a semi solid casting technique, in this case, stir casting. Subsequent research, need to add more than 1% Mg, because in this study Mg 1% effective up to 20% SiC_p. The addition of the element TiB more than 1.5% can improve the structure of grain.

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