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Influence wt.% of SiC and Borax on the Mechanical Properties of AlSi-Mg-TiB-SiC Composite by the Method of Semi Solid Stir Casting

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Abstract. SiC particle reinforced metal matrix composites (MMCs) with solid semi stir casting method is becoming popular in recent application (automotive, aerospace). Stirring the semi solid condition is proven to enhance the bond between matrix and reinforcement. The purpose of this study is to investigate the effect of the SiC wt.% and the addition of borax on mechanical properties of composite AlSi-Mg-TiB-SiC and AlSi-Mg-TiB-SiC/Borax. Specimens was tested focusing on the density, porosity, tensile test, impact test microstructure and SEM. AlSi is used as a matrix reinforced by SiC with percentage variations (10, 15, 20 wt.%). Giving wt.% Borax which is the ratio of 1: 4 between wt.% SiC. The addition of 1.5% of TiB gives grain refinement. The use of semi-solid stir casting method is able to increase the absorption of SiC particles into a matrix AlSi evenly. The improved composite presented here can be used as a guideline to make a new composite.

INTRODUCTION

Development of Metal Matrix Composites (MMCs) in science and technology, is a very important demand recently. Al-Si alloys have an important role in the field of aluminum foundry alloys. These materials have been widely used in the manufacture of automotive production, aircraft, aerospace manufacture of goods and the construction industry, due to the resilience of the material is very good. Composite material easy to weld, high corrosion resistant and has superior properties more [1]. Application of composite ranges from automotive, aviation, defense and others. AMC material on some of the components is required to be applied to high voltage, such as in the automotive field is a component of the drive shaft and the piston, the aviation sector is as helicopter blades and the field of defense, namely as track shoes from the tank [2].

Making MMCs combines aluminum alloy A356/Al7Si as a matrix with ceramic particles carbied silicon (SiC) as a reinforcement. Titanium alloy additions boron (TiB) as a grain refiner, because these properties can increase the strength and toughness of a material [3]. The use of SiC as reinforcement due to have good mechanical properties, namely, a density of 3.2 g/cm^3, a yield strength of 600 MPa, hardness Knop 2480 (HB 2170) and the elastic modulus of 400 GPa, and does not cause oxidation on metal. Alloy A356 has advantages such as light weight (density of 2.7 g / cm3), tensile strength of 172 MPa and resistant to corrosion however, has a low hardness that is,

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60 HB [4]. The addition of Mg (1% watt) to improve wettability matrix AlSi against SiC particles as reinforcement. Function Mg (1 wt%) increase wettability is, it can wet the surface of SiC reinforcement particles, thereby increasing the bonding strength of the matrix in SiC particles [5]. Research on AlSi7Mg2 reinforced SiC matrix (5-15 wt.%) results obtained on SiC maximal tensile strength (10 wt.%) of 280 MPa. For the hardness value increased in SiC (15 wt.%), Ie, HB 98 increased 48% [6]. The use of matrix A356, reinforcing SiC and Graphit with SIG (0-9 wt.%) results in maximal violence on SiC (9 wt.%) of 144VHN, increased hardness, but the elongation decreased [7]. Al6062 matrix with SiC amplifier (5, 10, 15, 20 wt.%) results obtained the highest hardness on SiC (20 wt.%) Namely 83 HRB [8]. Research on the use of Matrix 98.41% with SiC particles amplifier (5, 10, 15, 20, 25, 30 wt.%) the result that is, the best hardness to the percentage of SiC 25% ie 45.5 BHN [9]. The study examines the market AlTiC and AlTiC with variations of 0.2%, 0.5%, 1% got the result that the addition of 1% TiB grain size is getting smaller [10]. Al7178 alloys with variations TiB (1, 2, 3, 4 wt.%) To get the results that the addition of TiB between (1-4 wt.%) Butirnya decreased significantly in penambagan TiB (1 wt.%) Is equal to 140 µm , at (4 wt.%) to 55 µm [11]. The study, using master alloys AlTiB with a variation of 0.03% to 0.15% with the results of his research is the smallest grain size is 50 µm, achieved in a variation of 0.13% TiB [12].

The purpose of this study to see the effects of wt.% SiC and adding borax to the mechanical properties of composites AlSi-Mg-TiB-SiC and AlSi-Mg-TiB-SiC/Borax. The mixing process SiC ceramic particles into molten aluminum alloy matrix has two main drawbacks, namely, SiC particles are usually not wetted by the matrix liquid surface, and the second is their tendency to settle or SiC particles floating on the surface of the liquid matrix. This causes the distribution of SiC particles are not spread evenly to the surface of the matrix [13]. Research that has been carried out using semi-solid casting wheel for easy mixing SiC particles into the liquid matrix [14].

EXPERIMENTAL METHOD

Experiment composites AlSi-Mg-TiB-SiC and AlSi-Mg-TiB-SiC/Borax is made by using semi-solid methods stir casting. The alloy A356 / Al7Si is considered as a matrix. Mg 1 wt.% to improve wettability. TiB 1.5 wt.% to soften the grains in the matrix. SiC particles and the addition of borax as reinforcement in the matrix AlSi. Variation of SiC is used (10, 15, 20 wt.%). Increase wt.% borax which is the ratio of 1:4 between wt.% SiC. The following Table 1 chemical composition of the materials used and variations in every material weighing results are shown in Table 2.

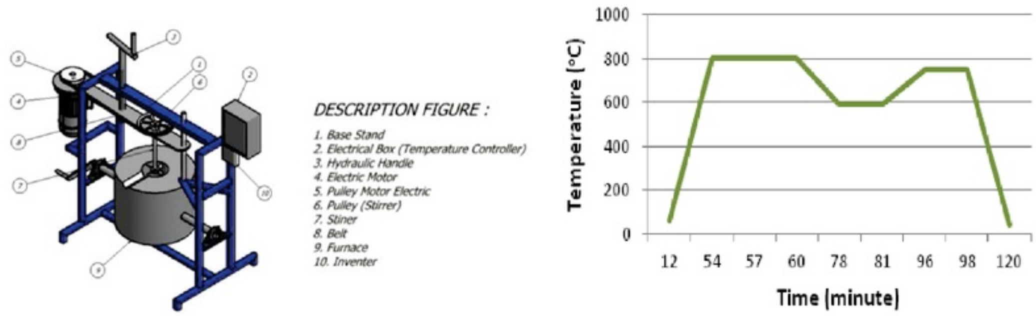
TABLE 1. Chemical composition of materials

Materials	Chemical composition (%)								
	Al	Si	SiC	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 (powder)	0.03	-	98.6	0.1	-	-	0.03	-	1.24
AlTiB (ingot)	93	0.16	-	0.16	5.00	0.98	-	-	0.05

TABLE 2. Variations in the composition of foundry

Composition (wt.%)	Al7Si (gram)	Mg (gram)	AlTiB (gram)	SiC (gram)	Total (gram)
Al7Si1Mg1.5TiB-SiC 0%	990	10	-	-	1000
Al7Si1Mg1.5TiB-SiC 10%	890	10	-	100	1000
Al7Si1Mg1.5TiB-SiC 15%	840	10	-	150	1000
Al7Si1Mg1.5TiB-SiC 20%	790	10	-	200	1000
Al7Si1Mg1.5TiB-SiC/Borax 10%	875	10	15	100	1000
Al7Si1Mg1.5TiB-SiC/Borax 10%	825	10	15	150	1000
Al7Si1Mg1.5TiB-SiC/Borax 10%	775	10	15	200	1000

First the process is to prepare the materials that will be melted is AlSi, Mg, and AlTiB. The materials are cut with machines suitable casting composition variation. Then the material is weighed to obtain the composition wt.% which has been set. Casting composition variation can be seen in Table 2. Then AlSi, Mg, and AlTiB put in an electric furnace. The following Fig. 1a electric furnace.



(a) (b)

FIGURE 1. (a) Electric furnaces stir casting, (b) Temperature vs time semi-solid stir casting process

And then it is heated to up temperatures of 800°C in order to obtain a liquid condition. Then the temperature was lowered to 590°C to obtain semi-solid condition. Meanwhile SiC particles and borax are heated in a separate place in the open electricity at a temperature of 400°C for 1200 seconds. Furthermore SiC and borax are included in an electric furnace and then stirred thoroughly using a mechanical stirrer. Rotational speed stirrer is 500 rpm for 180 seconds. Metal mold is also heated to a temperature of 300°C. Once everything is mixed and stirred in a state of semi-solid then the temperature is increased to temperatures of 750°C to obtain casting conditions. Results casting is cooled at room temperature 36°C. Fig. 1b. Shows the semi solid graph of temperature vs time. After that, composites was cut to fit the test specimen. Composite specimens were tested with the use, density test, tensile test, impact test, microstructure and SEM.

RESULTS AND DISCUSSIONS

Density and Porosity

The test specimen density is of 2cm x 2cm x 2 cm by using a digital balance VIBRA. Testing the density and porosity of the composite calculation results in AlSi-Mg-TiB-SiC and AlSi-Mg-TiB-SiC/Borax are shown in Table 3.

TABLE 3. Test results in density and porosity calculations

Composites (wt.%)	ρ_{actual} (g/cm^3)	$\rho_{theoretic}$ (g/cm^3)	Porosity
Al7Si1Mg1.5TiB-SiC 0%	2.64	2.68	1.49
Al7Si1Mg1.5TiB-SiC 10%	2.65	2.73	2.19
Al7Si1Mg1.5TiB-SiC 15%	2.67	2.76	2.22
Al7Si1Mg1.5TiB-SiC 20%	2.70	2.78	2.51
Al7Si1Mg1.5TiB-SiC/Borax 10%	2.68	2.70	1.51
Al7Si1Mg1.5TiB-SiC/Borax 15%	2.68	2.71	1.04
Al7Si1Mg1.5TiB-SiC/Borax 20%	2.71	2.73	1.18

Graphic image density and porosity of the composite AlSi-Mg-TiB-SiC and AlSi-Mg-TiB-SiC/Borax shown in Fig. 2 below:

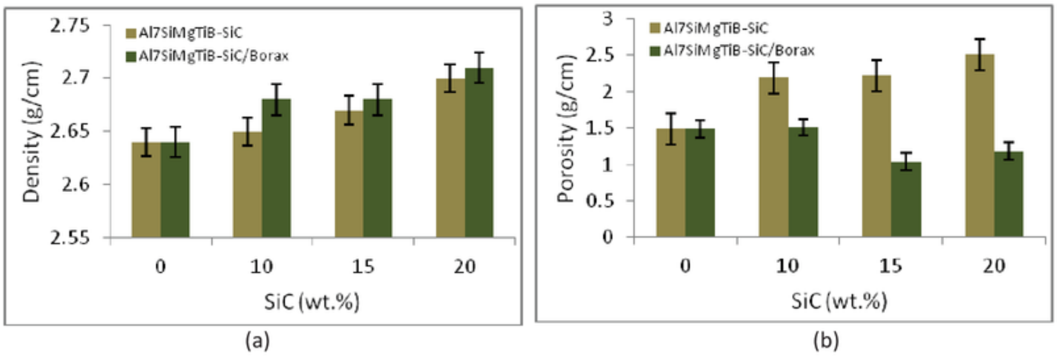


FIGURE 2. Graph (a) density, (b) the level of porosity AlSi-Mg-TiB-SiC and AlSi-Mg-TiB-SiC/Borax composite

Fig. 2a. shows that the density of the composite AlSi-Mg-TiB-SiC and AlSi-Mg-TiB-SiC/Borax increased with increasing SiC. As shown in Fig. 2b. it can be concluded that the addition of SiC mass will increase the porosity value. The addition of SiC by 10%, 15%, and 20% porosity value reached 1.51%, 1.67%, 2.347% and 2.42% but with the use of borax can reduce the value of the porosity of the composite. The use of borax in composites with reinforcement of 10%, 15% and 20% SiC porosity value fell to 0.73%, 1.04% and 1.18%. While the porosity value is lowest for the 10% SiC by using borax is 0.73%.

Tensile Test

The tensile strength is obtained by calculating the maximum load divided by the cross sectional area of the tensile test specimens. Tensile test is carried out by referring to the testing standards of ASTM E 8M-04 [[15]]. The following Table 4. the results of the tensile test.

TABLE 4. Test results of tensil strength calculations

Composites (wt.%)	σ_u (MPa)	σ_y (MPa)	%EL
Al7Si1Mg1.5TiB-SiC 0%	93	82	1.16
Al7Si1Mg1.5TiB-SiC 10%	120	94	1.86
Al7Si1Mg1.5TiB-SiC 15%	134	116	2.46
Al7Si1Mg1.5TiB-SiC 20%	143	132	2.98
Al7Si1Mg1.5TiB-SiC/Borax 10%	143	99	3.19
Al7Si1Mg1.5TiB-SiC/Borax 15%	150	122	3.87
Al7Si1Mg1.5TiB-SiC/Borax 20%	191	136	5.30

Effect of SiC percentage of the tensile strength composite AlSi-Mg-TiB-SiC and AlSi-Mg-TiB-SiC/Borax shown in Fig. 3.

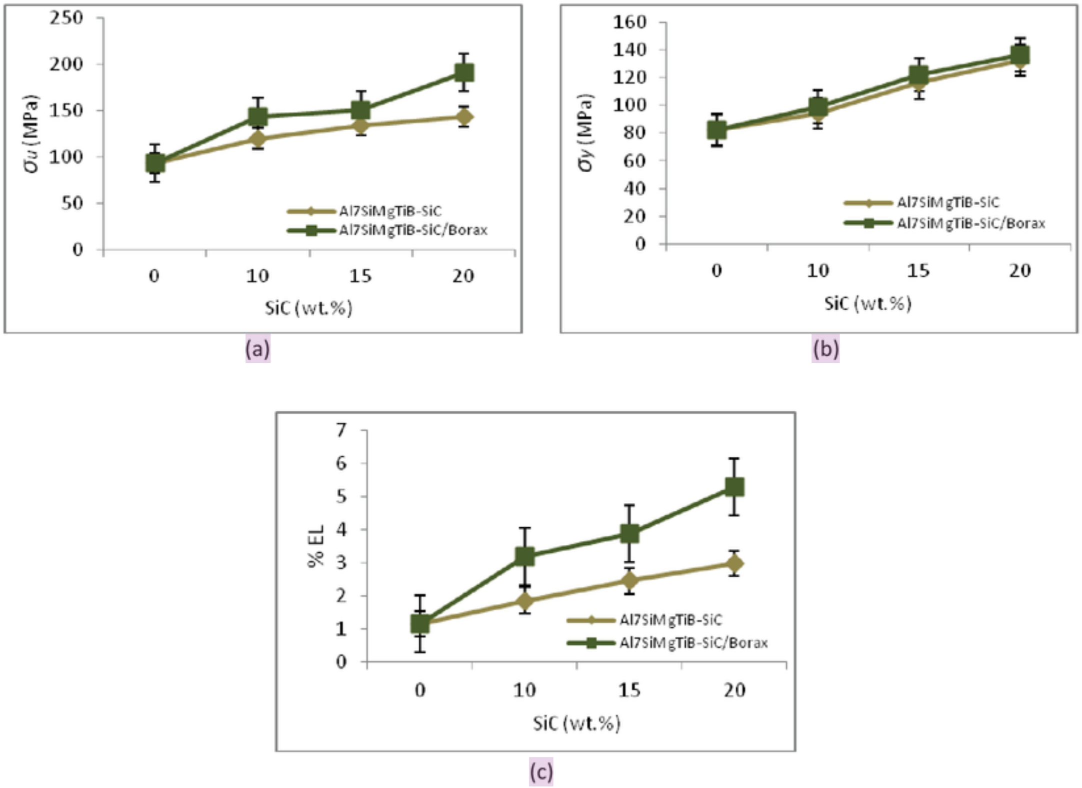


FIGURE 3. Graph (a) Tensile strength, (b) Yield strength, (c) Elongation,

AlSi-Mg-TiB-SiC dan AlSi-Mg-TiB-SiC/Borax Composite

Fig. 3a. it can be concluded that the tensile strength of the composite AlSi-Mg-TiB-SiC/Borax is higher than AlSi-Mg-TiB-SiC composites. Composite AlSi-Mg-TiB-SiC/Borax increases the tensile strength with increasing the mass of SiC is from 120 MPa to 143 MPa. The addition of borax compounds leads higher tensile strength is from 191 MPa. Fig. 3b. shows the yield strength to the composite AlSi-Mg-TiB-SiC is an average of 106 MPa. The yield strength of the composite AlSi-Mg-TiB-SiC/Borax is an average of 119 MPa. The yield strength of the composite AlSi-Mg-TiB-SiC/Borax is greater than the composite AlSi-Mg-TiB-SiC. Fig. 3c. it can be concluded that the composite AlSi-Mg-TiB-SiC/Borax has a higher ductility than AlSi-Mg-TiB-SiC composites. %EL in composite AlSi-Mg-TiB-SiC/Borax with the use of a heavy mass of SiC by 20% with a value of ductile of 5.3%.

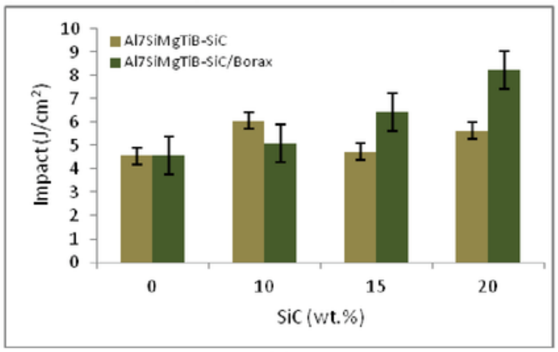
Impact Test

Impact test is based on ASTM standard E-23,02a [[16]]. The test results can be seen in Table 5.

TABLE 5. Results impact test

Composites (wt.%)	Weight Beater (Kg)	Price Impact (J/mm^2)
Al7Si1Mg1.5TiB-SiC 0%	1	4.56
Al7Si1Mg1.5TiB-SiC 10%	1	6.06
Al7Si1Mg1.5TiB-SiC 15%	1	4.73
Al7Si1Mg1.5TiB-SiC 20%	1	5.63
Al7Si1Mg1.5TiB-SiC/Borax 10%	1	5.10
Al7Si1Mg1.5TiB-SiC/Borax 15%	1	6.41
Al7Si1Mg1.5TiB-SiC/Borax 20%	1	8.23

Graphic image the relationship between price impact with variations percent SiC. The graph shown in Fig. 4.



(c)

FIGURE 4. The price impact composite AlSi-Mg-TiB-SiC and AlSi-Mg-TiB-SiC/Borax

Based on Fig. 4 it can be concluded that the price impact composites AlSi-Mg-TiB-SiC/Borax higher than AlSi-Mg-TiB-SiC composites. At composite AlSi-Mg-TiB-SiC price impact for the addition of 10%, 15% and 20% respectively is 4.06 J/cm^2, 4.73 J/cm^2, and 5.63 J/cm^2. In addition some variations of SiC with relatively fixed percentage of the price impact. In composite AlSi-Mg-TiB-SiC/Borax price impact for the addition of SiC 10%, 15% and 20% respectively was 5.1 J/cm^2, 6.4 J/cm^2 and 8.2 J/cm^2. The addition of SiC composites can improve the value of impact.

Micro Structure

Testing microstructure is done using an optical microscope Olympus. The images of micro composite AlSi-Mg-TiB-SiC and AlSi-Mg-TiB-SiC/Borax attitude is shown in Fig 5.

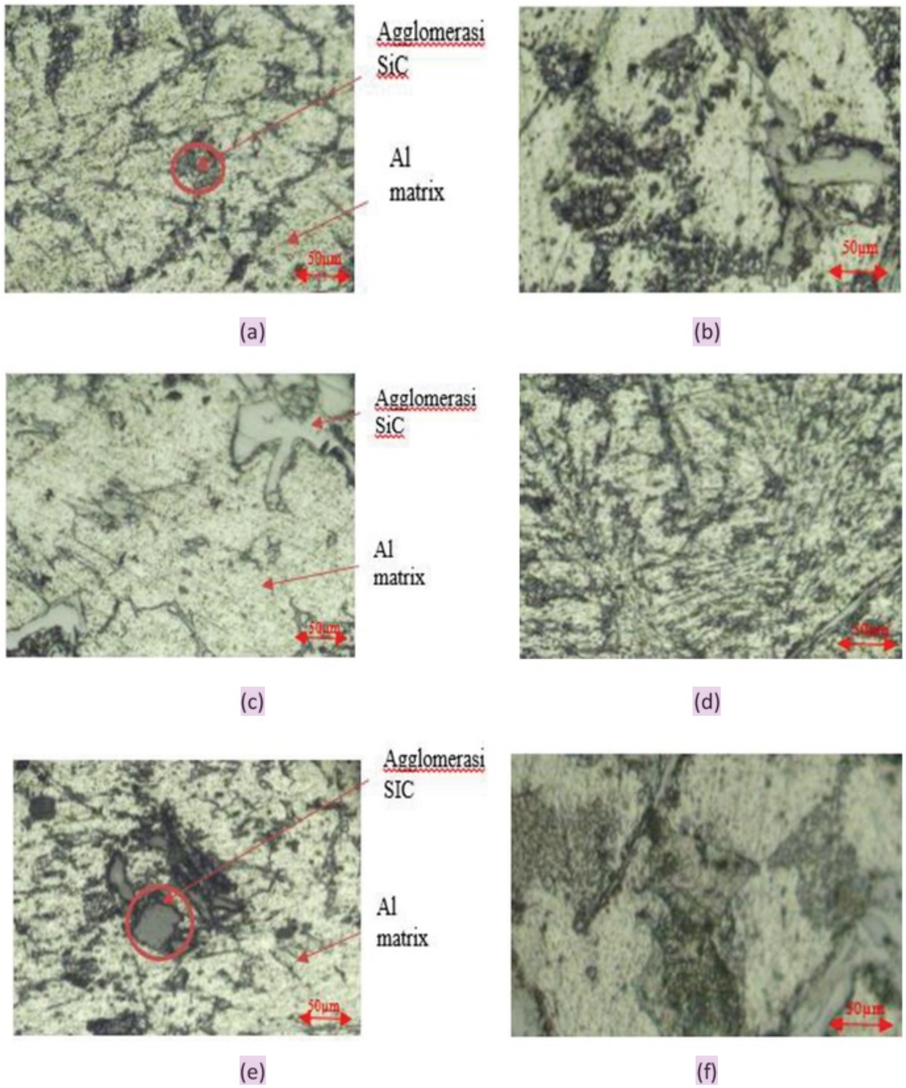


FIGURE 5. Composite macro photo: (a) AlSi-Mg-TiB-SiC 10% (b) AlSi-Mg-TiB-SiC/Borax 10% (c) AlSi-Mg-TiB-SiC 15% (d) AlSi-Mg-TiB-SiC/Borax 15% (e) AlSi-Mg-TiB-SiC 20% (f) AlSi-Mg-TiB-SiC/Borax 20%

Fig. 5 Shows that the greater the level of SiC in the composite, the more SiC bound in a matrix. Agglomeration SiC looked irregularly shaped with a dark gray color. SiC particles randomly dispersed and relatively evenly distributed in the matrix AlSi-Mg-TiB-SiC and AlSi-Mg-TiB-SiC/Borax. This is consistent with the research of Hashim, et al (2001) which states that the semi-solid casting wheel will help improve wettability and dispersion of reinforcing particles homogeneously [5].

The Results of Morphology

Testing Scanning Electron Microscopy (SEM) shows the distribution of SiC particles in the matrix AlSi. The results of SEM observation in morphology with a magnification SEM images AlSi-Mg-TiB-SiC 10.000X produce and AlSi-Mg-TiB-SiC/Borax shown in Fig 6. below.

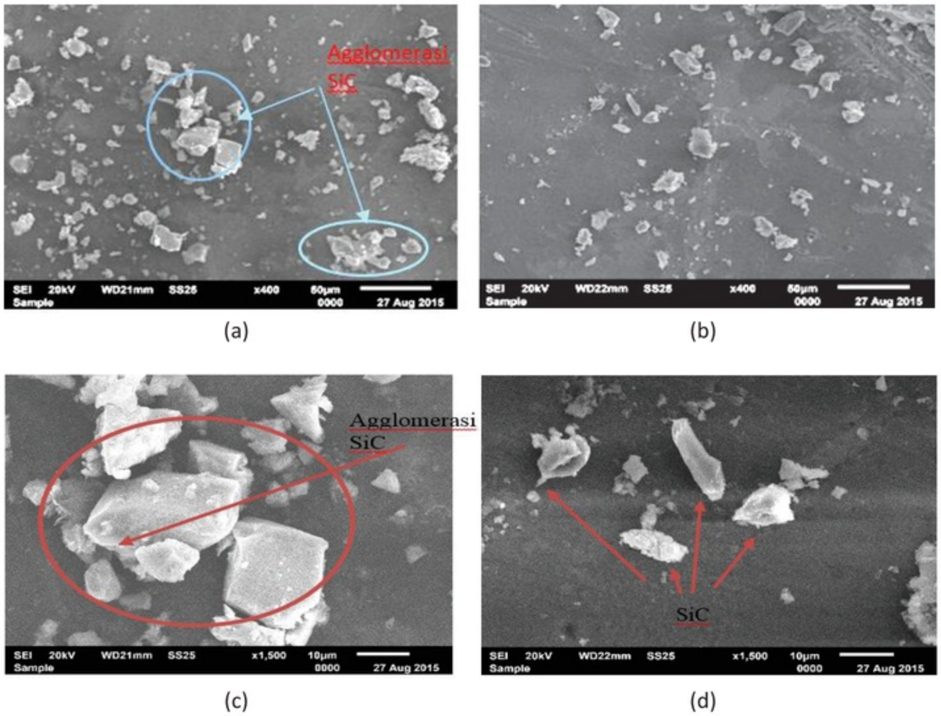


FIGURE 6. SEM Composite: Morphology (a) AlSi-Mg-TiB-SiC 20 wt.% (b) AlSi-Mg-TiB-SiC/Borax 20 wt%

Fig. 6 (a, b) shows that there are agglomerations on the surface of composite matrix AlSi-Mg-TiB-SiC, while in the Fig. 6 (c, d) there is no agglomeration of the composite AlSi-Mg-TiB-SiC/Borax. It was concluded that the spread of SiC with the use of borax in the mixture AlSi-Mg-TiB-SiC composites there is no agglomeration of the matrix.

CONCLUSION

Results of the data analysis in this study can be concluded as follows: Porosity will increase with the increase in the number of heavy mass of SiC. The use of borax can lower porosity values, lowest porosity value of 0.7% which contained in the AlSi-Mg-TiB-SiC/Borax (10 wt.%). The highest value of 2.6% porosity contained in the composite AlSi-Mg-TiB-SiC/Borax (20 wt.%). The highest tensile strength of the composite AlSi-MgTiB-SiC/Borax (20 wt.%) Ie 191 MPa. The impact value has highest point in the composite AlSi-Mg-TiB-SiC/Borax (20 wt.%) of 8.2 J/cm^2. The micro-structure of composite AlSi-Mg-TiB-SiC agglomeration contained on the surface of the matrix. The addition in of borax compounds composite AlSi-Mg-TiB-SiC/Borax, SiC particles spread more evenly. The morphology of SEM test results of composite AlSi-Mg-TiB-SiC and AlSi-Mg-TiB-SiC/Borax between reinforcement and matrix particles can be fused and well dispersed.

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