Biomedical and Mechanical Engineering Journal (BIOMEJ)
e-ISSN: 2776-1983, p-ISSN: 2829-5242
Vol. 2, No.2, October 2022, pp 1-12

Microstructure on the TiB and Mg Reinforced of Al356 Alloy with Die Casting Process

E.I. Bhiftime[1,*]

[1] Mechanical Engineering Department, Indonesia Defense University, IPSC Area, Sentul, Bogor, West Java 16810, Indonesia

*Corresponding e-mail: eka.bhiftime@idu.ac.id

Abstract. Metal matrix composites (MMC) reinforced with titanium boron and magnesium offer high mechanical and good physical. Al356 alloy reinforced with TiB and Mg particles in die casting prosses was the most simple way. The purpose of the study was to investigate the difference of the microstructure to Al356 alloy reinforced of TiB and Mg particles, as well as the changing effects on the extra level of TiB and Mg. The base materials used were Al356 alloy as the matrix and TiB and Mg as the reinforcement (3, 4, 5 wt%). The casting prosses used in the study was the die casting. The microstructure of the composites fabricated by different parameters indicated that semi-solid method resulted improved in homogeneous particle distribution 3–5 wt% TiB and Mg composites were fabricated by the novel processing. The particle distribution was uniform in these composites. Grain sizes of composites will be much smoother by giving TiB. The Grain sizes of were enhanced as the particle contents increased. The morphology of the composite between the reinforcing particle to the Al356 alloy matrix was to unite and to be dispersed evenly. This article only discusses micro and SEM.

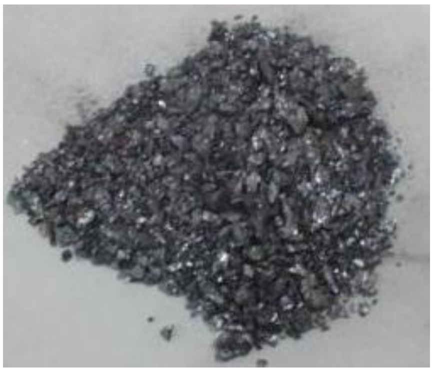
Keyword: Alumunium alloy, Mg, TiB, Die Casting.

1. Introduction

Aluminum matrix composites have become of great interest in the lightweight fields because of their high specific stiffness and high specific strength [1–3]. However, aluminum matrix composites are limitedly used due to their high cost. Their high cost usually comes from three aspects: reinforcements, fabrication processing, and secondary deformation. Thus, economical particles and high efficient production methods should be developed. Micro particles are very economical because of their low prices and easy dispersion during fabrication. The micro particle reinforced aluminum matrix composites own the potential commercial use for its relatively low cost and good mechanical properties. Micro particle reinforced metal matrix material is usually produced by powder metallurgy, high-energy ball milling, sputtering and stir casting [4–6], etc. Among all of these methods, stir casting is regarded as the most productive and economical. However, long stir time is necessary to obtain uniform particle distribution. This often results in too much gas and oxidation to Mg matrix. Thus, it is a need to reduce the stirring time to fabricate high-quality composites [7–9]. The manufacture of aluminum alloy is a combination of A356 as a matrix with Magnesium (Mg) and Titanium Boron particles as reinforcement because these properties can increase the strength and toughness of a metal. Alloy A356 has advantages such as light weight (density 2.7 g/cm3), tensile strength of 172 MPa and resistance to corrosion, but has a low hardness of 60 HB [10-12]. Research on AlTiC and AlTiB with variations of 0.2%, 0.5%, 1% got the result that with the addition of 1% TiB the grain size was getting smaller [13-15]. Alloy Al7178 with variations of TiB (1, 2, 3, 4 wt.%) obtained the result that the addition of TiB between (1-4 wt.%) the grains decreased significantly in the mining of TiB (1 wt.%) which was 140 m , at (4 wt.%) to 55 m [16-18]. The study used master alloys AlTiB with a variation of 0.03% to 0.15% with the results of the study being that the smallest grain size was 50 m, achieved at a variation of 0.13% TiB [15]. Generally, the nanoparticles reinforced composites have been produced using a variety of methods: stir casting [18-20], disintegrated melt deposition, powder metallurgy, etc. However, stir casting method is preferred to other techniques due to its capability of producing complex shapes at a high production rate and low costs [19]. The purpose of the study was to investigate the difference of the microstructure of Al356 alloy, as well as the changing effects on the extra level of TiB and Mg. Specimens were tested focusing on the microstructure and SEM.

2. Experimental Method

The research is viewed from the mechanical properties, the results of the casting using the die casting process. The main material used is aluminum alloy Al356, with variations in the addition of elements Mg (3, 4, 5) wt% and TiB 2 wt%. The addition of Mg and TiB can improve the mechanical properties of the castings. Here is Fig 1 of the materials used, and Table 1 is the composition of the ingredients.



(a)

(b)

(c)

Figure 1. Materials used in casting (a) Mg, (b) TiB, (c) Al356.

Biomedical and Mechanical Engineering Journal (BIOMEJ)
e-ISSN: 2776-1983, p-ISSN: 2829-5242
Vol. 2, No.2, October 2022, pp 1-12

The following is Table 1 The composition of the ingredients.

Table 1. Chemical composition of materials

Materials	Chemical composition (%)						
	Si	Mg	Al	Fe	Cu	Mn	Other
Al356 (ingot)	10.34	0.27	85.41	0.87	1.81	0.16	1.017
Mg	0.013	99.93	0.022	0.003	0.012	0.012	0.018
TiB	0.16	-	93	0.16	-	-	0.05

The first stage of this process is to prepare the material to be melted. These ingredients are cut into small pieces according to the ratio of the mixing weight. This is done to simplify the process of setting the mixing composition. Each material is weighed to obtain the mass composition according to the variation of casting. The results of weighing materials for each variation are shown in Table 2.

Table 2. Variations in the composition of foundry

Materials (wt%)	Al356 (gram)	TiB (gram)	Mg (gram)	Total (gram)
Al356+TiB 2% Mg 0%	500	-	-	500
Al356+TiB 2% Mg 3%	450	20	30	500
Al356+TiB 2% Mg 4%	440	20	40	500
Al356+TiB 2% Mg 5%	430	20	50	500

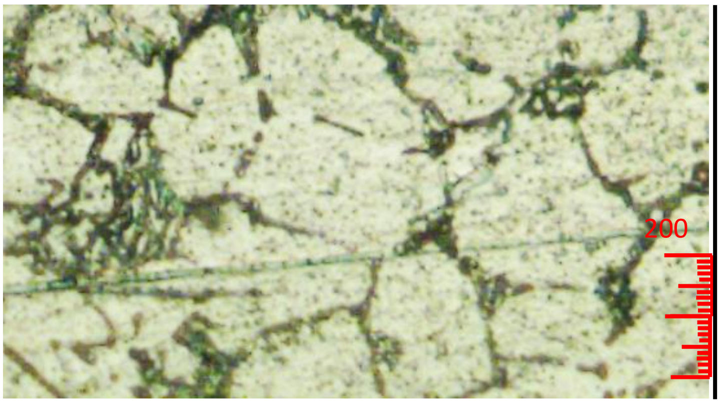
In the next process, the material melts into the heating furnace. First Al356 is heated to a temperature of 800 °C to reach a complete liquid state. Then the temperature is lowered to 640 °C, then Mg and TiB are put into the heating furnace. It is then thoroughly stirred by a mechanical stirrer. The rotational speed of the stirrer is 200 rpm and the stirring time is 120 seconds. Then it must be heated again to a pouring temperature of 760 °C. The mold metal is also heated to a temperature of 250 °C, then poured into the mold. Then allowed to stand for 360 seconds, and released from the die casting mold. After that, the casting is cooled at room temperature. Furthermore, the casting results are cut into pieces according to the test specimen. Here is Fig 2. casting results.

Figure 2. Casting results, and dividing the test area boundaris.

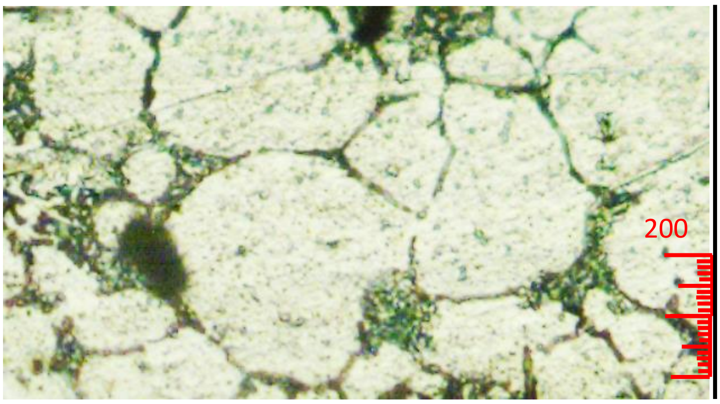
3. Results and Discussions

3.1. Microstructure

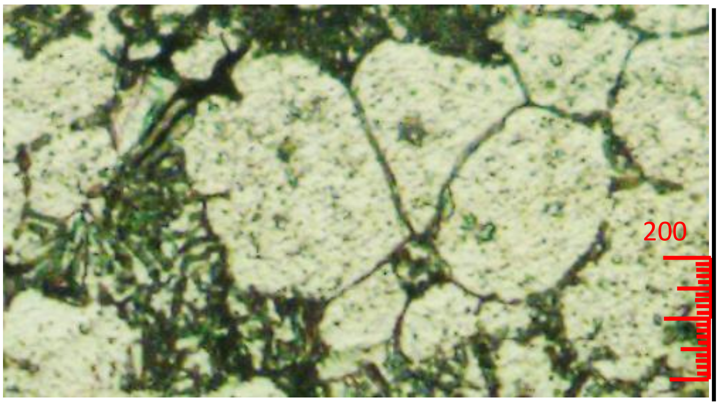
The microstructure testing by using Olympus, an optical microscope with a magnification of 200X, produced photos structure micro of Al356MgTiB and Al356MgTiB in Fig. 4 and 5 below.



(a)



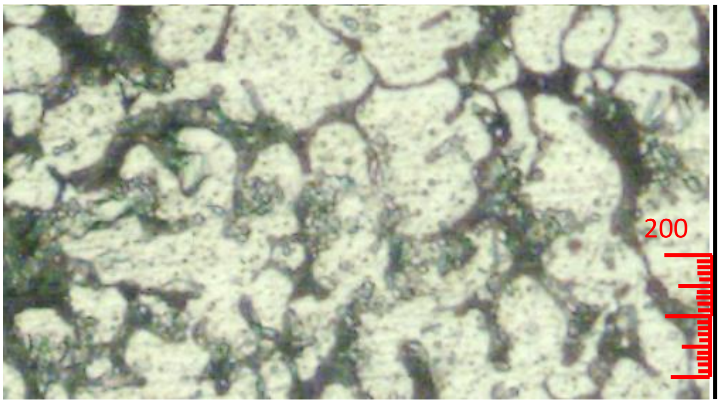
(b)



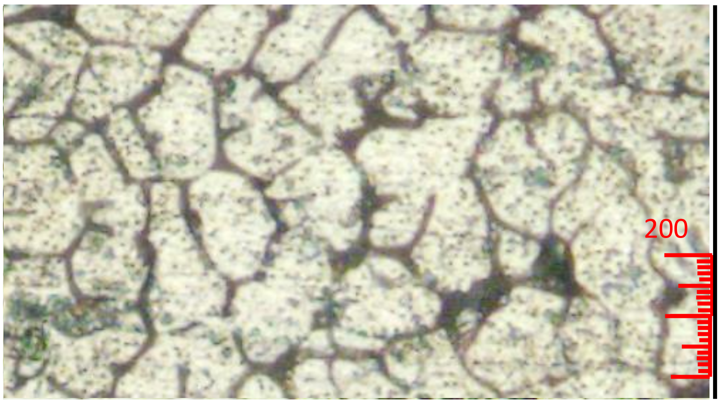
(c)

Figure 3. Micro Al-TiB-Mg 0% wt (a) Top, (b) Center, (c) Battom

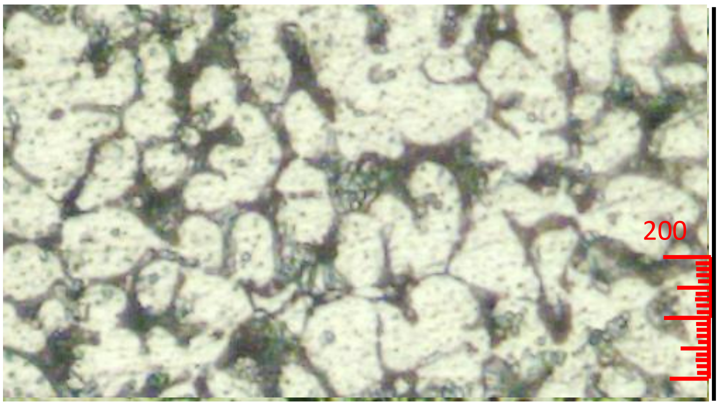
Biomedical and Mechanical Engineering Journal (BIOMEJ)
e-ISSN: 2776-1983, p-ISSN: 2829-5242
Vol. 2, No.2, October 2022, pp 1-12



(a)

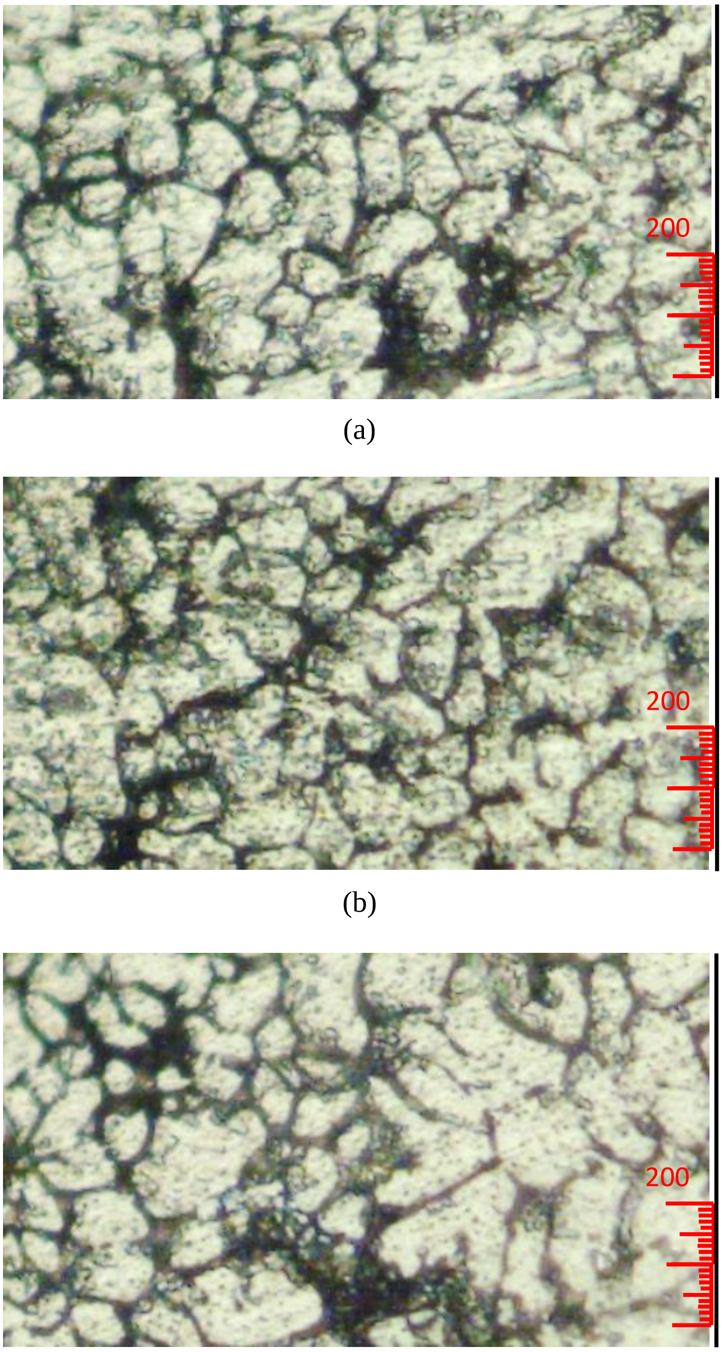


(b)



(c)

Figure 4. Micro Al-2TiB-Mg 3% wt (a) Top, (b) Center, (c) Battom



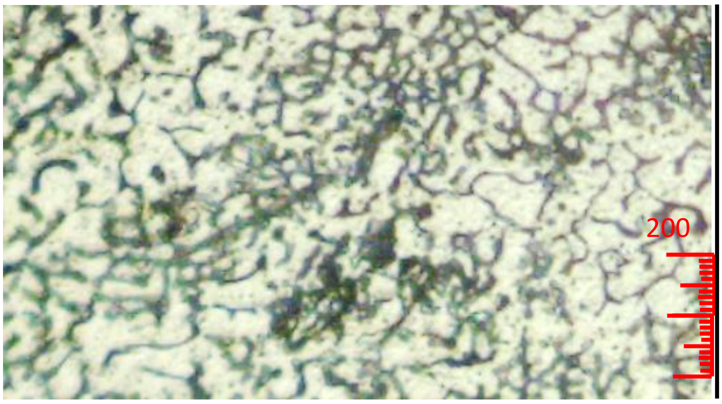
(a)

(b)

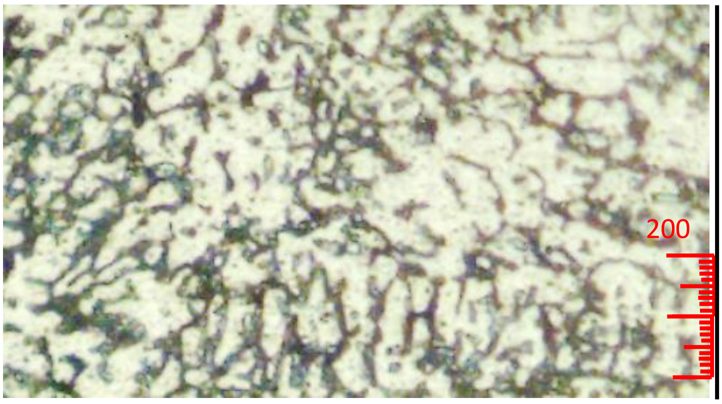
(c)

Figure 5. Micro Al-2TiB-Mg 4% wt (a) Top, (b) Center, (c) Battom

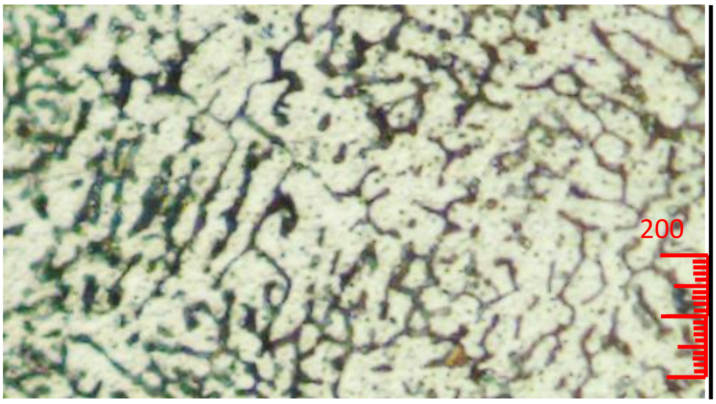
Biomedical and Mechanical Engineering Journal (BIOMEJ)
e-ISSN: 2776-1983, p-ISSN: 2829-5242
Vol. 2, No.2, October 2022, pp 1-12



(a)



(b)



(c)

Figure 6. Micro Al-2TiB-Mg 5% wt (a) Top, (b) Center, (c) Battom

Fig 3. Micro Al-TiB-Mg 0% wt shows that the grain size is very large when compared to Al-2TiB-Mg 3% wt, Al-2TiB-Mg 4% wt, and Al-2TiB-Mg 5% wt because it is not the addition of the percent TiB and Mg elements given. TiB and Mg elements can improve the finer grain size in the casting results. Fig Micro Al-TiB-Mg 0% wt Top, Center, and Battom gives relatively the same grain size. This is like the results of research Hashim, et al. (1999) which stated that the potential for grain size improvement in the casting process was caused by a chemical reaction between the reinforcing particles and the alloy which resulted in good grain size with the addition of TiB and good adhesion after the addition of Mg element. Fig 4. Micro Al-TiB-Mg 3% wt showed smaller grain size when compared to Al-TiB-Mg 0% wt. However, when compared with Al-2TiB-Mg 4% wt and Al-2TiB-Mg 5% wt the grain size was slightly larger. Fig 6. Micro Al-TiB-Mg 5% wt shows finer grain size when compared to Al-TiB-Mg 3% wt and Al-2TiB-Mg 4% wt, because the addition of percent Mg has an impact on adhesion and size changes. item. Al-TiB-Mg 5% wt between the Top, Center, and Battom gave relatively the same grain size.

3.2. Calculation of Grain Size

The grain size calculation uses the linear intercept method according to the ASTM E112-96 standard, the aim is to compare Al354 with the addition of TiB and Mg with Al354 without the addition of TiB and Mg. The results of the calculation of grain size data are obtained as shown in Table 3. below..

Table 3. Grain size calculation

Materials	Test Area	Diameter grain size (μm)	Diameter Average grain size (μm)
	Top	110.50	
Al356 +TiB+Mg 0 wt%	Center	108.70	109.46
	Battom	109.20	
	Top	73.33	
Al356 +2TiB+Mg 3 wt%	Center	70.40	71.84
	Battom	71.80	
	Top	52.68	
Al356 +2TiB+Mg 4 wt%	Center	52.14	52.12
	Battom	51.54	
	Top	34.87	
Al356 +2TiB+Mg 5 wt%	Center	35.35	35.09
	Battom	35.07	

The density and porosity graph of the casting results with the percentage of Mg is shown in Fig 7and 8 below:

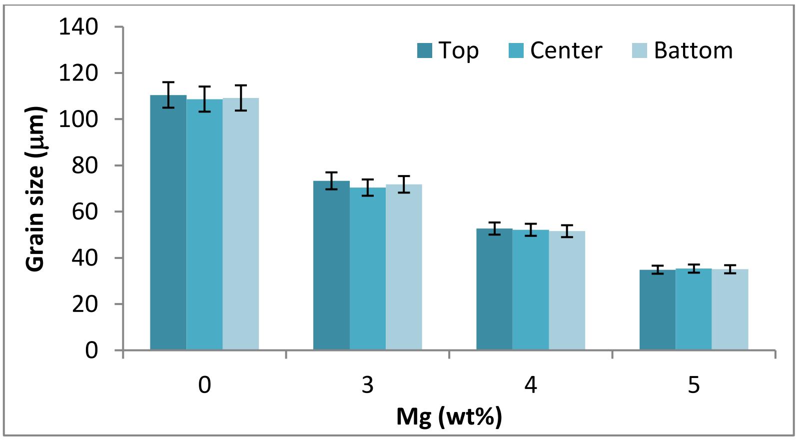


Figure 7. Diameter grain size calculation AlTiBMg

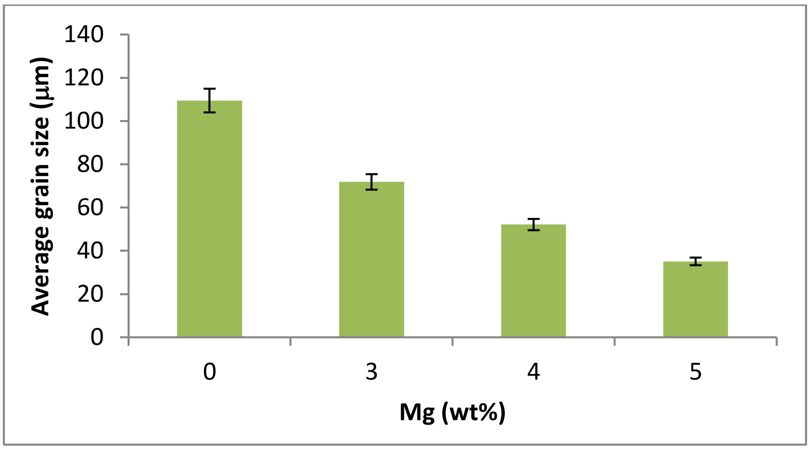
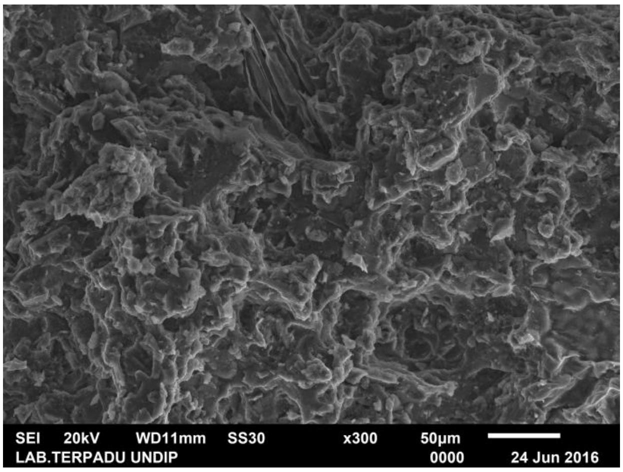


Figure 8. Diameter Average grain size calculation AlTiBMg

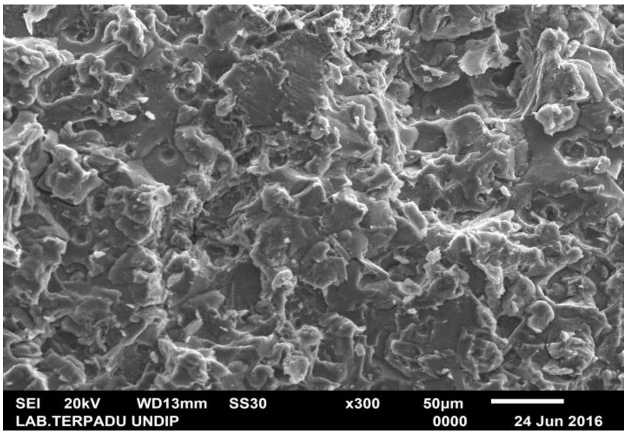
Fig 7. The result of the grain size calculation shows that the grain diameter for each element variation is Al-TiB-Mg 0 wt%, Al-2TiB-Mg 3 wt%, Al-2TiB-Mg 4 wt%, and Al-2TiB-Mg 5 wt%, has relatively the same grain size values for the Top, Center, and Battom sections. Fig 8. The average value in each section of the variation between Top, Center, Battom is Al-TiB-Mg 0 wt%, which is 109.46 µm, Al-2TiB-Mg 3 wt% is 71.84 µm, Al-2TiB-Mg 4 wt% is 52.12 µm, Al-2TiB-Mg 5 wt% is 35.09 µm. The difference in grain size values between the variations of Al-2TiB-Mg 3 wt%, with Al-2TiB-Mg 4 wt% is 52.12 µm. While the variation of Al-2TiB-Mg 4 wt% with Al-2TiB-Mg 5 wt% is 17.03 µm. So that the variation of Al-2TiB-Mg 5 wt% has the smallest grain size value when compared to other variations. The average change of grain size in each variation is 35.59 µm.

3.3. Marphology Test

The morphology image with the magnification of 300X and 500X produced the micro-photos of Al-TiB-Mg in Fig. 8 below.

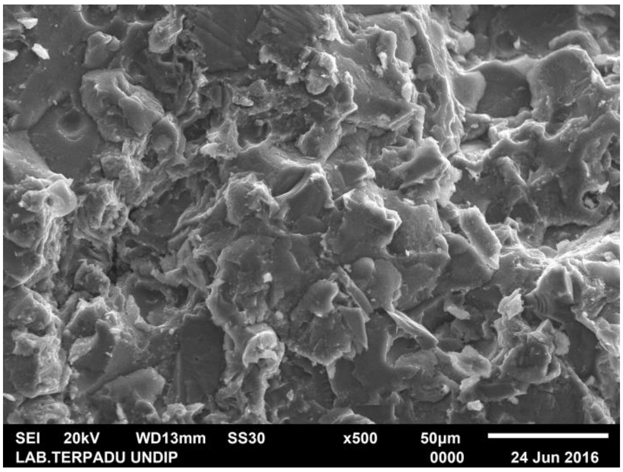


(a)

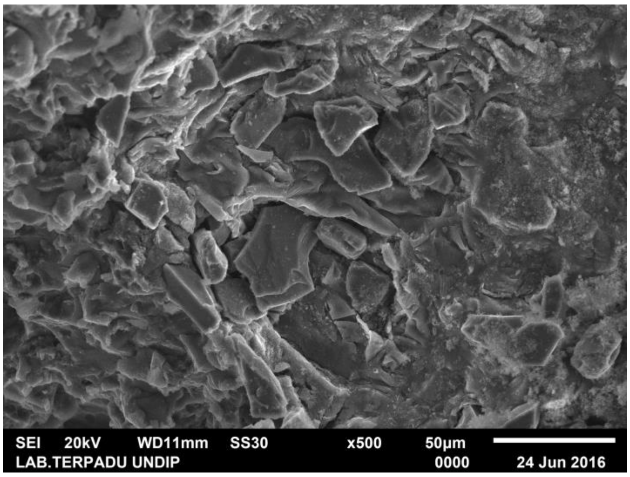


(b)

Figure 9. Morphology Magnification 300X



(a)



(b)

Figure 10. Morphology Magnification 500X

Fig. 9 and 10 The morphology Al-2TiB-Mg between the reinforcing particles and the matrix can be uniformly fused. In the Al-2TiB-Mg variation there are Mg particles surrounding the Al alloy matrix which bind to each other. Meanwhile, Al-2TiB-Mg can be seen between TiB-Mg and Al alloy matrix that can mix well. Then the addition of TiB can cause changes in the shape of the particles to be smoother and more evenly distributed.

4. Conclusion

The results of this study are as follows: Micro Al-TiB-Mg 5% wt shows finer grain size when compared to Al-TiB-Mg 3% wt and Al-2TiB-Mg 4% wt, because the addition of percent Mg has an impact on adhesion and size changes. item. Al-TiB-Mg 5% wt between the Top, Center, and Battom gave relatively the same grain size. The difference in grain size values between the variations of Al-2TiB-Mg 3 wt%, with Al-2TiB-Mg 4 wt% is 52.12 μm. While the variation of Al-2TiB-Mg 4 wt% with Al-2TiB-Mg 5 wt% is 17.03 μm. So that the variation of Al-2TiB-Mg 5 wt% has the smallest grain size value when compared to other variations. The average change of grain size in each variation is 35.59 μm. In the Al-2TiB-Mg variation there are Mg particles surrounding the Al alloy matrix which bind to each other. Meanwhile, Al-2TiB-Mg can be seen between TiB-Mg and Al alloy matrix that can mix well. Then the addition of TiB can cause changes in the shape of the particles to be smoother and more evenly distributed. Morphology Al-2TiB-Mg between the reinforcing particles and the matrix can be uniformly fused.

References

[1] Bedolla E, Lemus-Ruiz J, Contreras A. Synthesis and characterization of Mg–AZ91/AlN composites. Mater Des 2012;38:91–8.
[2] Habibi MK, Joshi SP, Gupta M. Hierarchical magnesium nano-composites for enhanced mechanical response. Acta Mater 2010;58:6104–14.
[3] Wang XJ, Hu XS, Wu K, Zheng MY, Zhen L, Zhai QJ. The interfacial characterization of SiCp/AZ91 magnesium matrix composites fabricated by stir casting. J Mater Sci 2009;44:2759–64.
[4] Hassan SF, Gupta M. Development of high performance magnesium nanocomposites using nano-Al2O3 as reinforcement. Mater Sci Eng A 2005;392:163–8.
[5] Abdizadeh H, Ashuri M, Moghadam PT, Nouribahadory A, Baharvandi HR. Improvement in physical and mechanical properties of aluminum/zircon composites fabricated by powder metallurgy method. Mater Des 2011;32:4417–23.
[6] Lu L, Thong KK, Gupta M. Mg-based composite reinforced by Mg2Si. Compos Sci Technol 2003;63:627–32.
[7] Hassan SF, Gupta M. Development of high strength magnesium based composites using elemental nickel particulates as reinforcement. J Mater Sci 2002;37:2467–9.
[8] Wang SJ, Wu GQ, Ling ZH, Huang Z. Microstructure and mechanical properties of YAl2 reinforced MgLiAl composite. Mater Sci Eng A 2009;518:158–61.
[9] Cai Y, Tan MJ, Shen GJ, Su HQ. Microstructure and heterogeneous nucleation phenomena in cast SiC particles reinforced magnesium composite. Mater Sci Eng A 2000;282:232–5.
[10] Sajjadi SA, Ezatpour HR, Torabi Parizi M. Comparison of microstructure and mechanical properties of A356 aluminum alloy/Al2O3 composites fabricated by stir and compo-casting processes. Mater Des 2012;32:106–11.
[11] Hashim, J., Looney, L., Hashmi, MSJ., 1999, "Metal Matrix Composites: Production by The Stir Casting Method", *Journal of Material Processing Technology*, Vol. 92-93, pp. 1-7.
[12] Hashim, J., Looney, L., Hashmi, MSJ. The Wettability of SiC Particle in Cast Aluminium Matrix Composites. Journal of Material Processing Technology. 119, (2001). pp. 329-335.
[13] Zhu M, Jian ZY, Yang GC, Zhou YH. Effects of T6 heat treatment on the microstructure, tensile properties, and fracture behavior of the modified A356 alloys. Mater Des 2012; 36:243-9.

[14] Lin, G., Hongwei, Z., Hoaze, Li., Lina, G. Effect of Mg Content on Microstructure and Mechanical Properties of SiCp/Al-Mg Composites Fabricated by Semi Solid Stirring Technique. Trans Nonferrous et. Soc. 20, (2010), pp. 1851-1885.

[15] Viswanatha, BM., Kumar, P.M., Basavarajappa, S. Mechanical Properties Evaluation of A356/SiCp/Gr Metal Matrix Composites. Journal of Engineering Science and Technology. 8, (2013), pp. 754-763.

[16] Mondal D.P, Nidhi JHA, Anshul Badkul, S.DAS. Effect of Al-TiB master alloy addition on microstructure, wear and compressive deformation behavior of aluminium alloys. Trans. Nonferrous Met. Soc. China 22(2012).

[17] LI Jian-guo, YE Wei, LI Li, HUANG Min. Preparation of AlTiC Master Alloy Under Ultrasonic Vibration. CN 200410103904.3, 2004. (in Chinese).

[18] Yar AA, Montazerian M, Abdizadeh H, Baharvandi HR. Microstructure and mechanical properties of aluminum alloy matrix composite reinforced with nano-particle MgO. J Alloys Compd 2009;484:400–4.

[19] Prasad Y, Rao KP, Gupta M. Hot workability and deformation mechanisms in Mg/nano-Al2O3composite. Compos Sci Technol 2009;69:1070–6.

[20] Nguyen QB, Gupta M. Increasing significantly the failure strain and work of fracture of solidification processed AZ31B using nano-Al2O3 particulates. J Alloys Compd 2008;459:244–50.