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ADDITION OF MAGNESIUM (Mg) WITH ALUMINA (AL_2O_3) REINFORCER IN ALUMINUM MATERIAL COMPOSITES ON THE MECHANICAL PROPERTIES AND MICRO STRUCTURES

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ABSTRACT: Aluminum is a widely used and applied material in daily life or in the industrial and automotive world. In order to improve the performance and properties of the application to be used, it needed an alloying element to improve the mechanical properties of the Aluminum. Aluminum Matrix Composite (AMC) or better known as Aluminum matrix composite is one type of material that has great potential to be developed, due to its good combination and properties such as high strength and hardness, low density, low density, capable of good machining, and its basic ingredients are easily found on the market and cheaper than other materials. This research was conducted using the stir casting process to be able to mix all the compositions contained in Aluminum matrix composites and to help the distribution of alumina reinforcing particles (Al_2O_3) and Aluminum matrices be evenly distributed. The parameters used in this casting process are varying the volume fraction of the Al_2O_3 amplifier by 0.5%; 1.5% and 2.5% plus the magnesium content remains 0.9%. The results showed that the addition of Al_2O_3 can increase the value of hardness and reduce the value of tensile strength. The highest hardness value was 75.3 HRB at the addition of Al_2O_3 by 2.5% and the lowest tensile strength value was 7.17 Kgf / mm^2 with the percentage of Al_2O_3 addition of 0.5%.

Keywords: Aluminum matrix composite, steering casting, wettability, mechanical properties.

1. Introduction

Basically the principle of metallurgical science discusses all aspects of how the metal is processed, starting from the initial refining process until the metal is combined and formed to become a product for components whose application is found in the industrial and non-industrial world[1]. Metal grouping is divided into two namely, the groups of ferrous and non-ferrous metals. As an example, Aluminum is a non-ferrous metal whose use and application are numerous and have a very important role in daily life, given that Aluminum has excellent corrosion resistance properties, thus allowing Aluminum-based materials not to be easily corroded (rust). Besides that Aluminum has light and strong properties. In this case, it is very much needed in the automotive world as a material selection to support the manufacture of engine components that require high performance with good quality.

Aluminum composite or known as AMC (Aluminum Matrix Composites) is one type of material that has great potential to be developed. That is because the combination of good properties, such as high strength and hardness, low density, good machining, the basic materials are easily available on the market, and the prices are quite affordable and compete with other materials. In its utilization, AMC is widely used in the automotive, aviation, defense and other industries. AMC is widely used in applications that require high performance, such as applications in aircraft machining as well as applications in the automotive industry [2]. One effort to improve the mechanical properties of AMC is to add Alumina (Al_2O_3) reinforcement where Al_2O_3 is a ceramic material, which has very hard characteristics and has properties that can withstand high temperatures. Then by adding Magnesium (Mg) particles as a wetting agent in order to improve the wettability between the metal matrix and the reinforcement can bind to each other well.

This study will add Magnesium (Mg) alloys with reinforced alumina (Al_2O_3) which is composed, aiming to determine changes in mechanical properties and microstructure produced by Aluminum matrix composites after being combined.

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1.1 Problem of Study

What is the effect of adding Alumina (Al2O3) and Magnesium (Mg) reinforcement to the mechanical properties and microstructure of Aluminum Matrix Composites?

1.2 Purpose of Study

This study aimed to determine changes in mechanical properties and microstructure of adding Alumina (Al_2O_3) and Magnesium (Mg) alloys to Aluminum matrix composites.

2. Research Method

The material used in this study is Aluminum 1100 series as a matrix, reinforcing particles in the form of alumina (Al_2O_3), and the addition of magnesium alloys used as wetting agents. Then the entire composition of the material is melted / thawed in the kitchen is crucial until it reaches its liquid temperature by using the casting method to help spread the particles to the liquid matrix.

The parameters used in this study are by varying the percentage of the addition of Al_2O_3 reinforcement particles by 0.5%; 1.5% and 2.5% with pouring temperature of 800°C, stirring speed of 500 Rpm for 5 minutes. The research variables used in making Aluminum Composite Matrix are the amount of Aluminum as a matrix of composites, Al_2O_3 which is used as reinforcing particles and Magnesium (Mg) as alloys in composites.

Table 1 Number of Al Volume Matrices, Al2O3 Particles, and Mg

Speciment number	Aluminium (%)	AL_2O_3 (%)	Mg (%)
1	100	0	0
2	98.6	0.5	0,.9
3	97.6	1.5	0.9
4	96.6	2.5	0.9

3. Result and Discussion

After conducting mechanical testing which includes testing tensile, hardness, porosity, microstructure and SEM, the data obtained can then be analyzed as follows:

3.1 Tensile Testing

Table 2 Tensile Testing Data

No	Variasi	Jumlah Spesimen	Area (Mm^2)	Max Force (Kgf)	0.2% Y.S (Kgf/mm^2)	Tensile Straing (Kgf/mm^2)	Elongation (%)
1	Al 1100	A	120.75	1250	6.64	10.35	24.5
		B	120.75	1102	5.79	9.12	24.5
		C	120.75	1052	5.54	8.75	22
	Rata - Rata Tensile Strength					**9.41**	
2	Al_2O_3 0.5%	A	120.75	824	4.61	6.72	13
		B	120.75	975	5.38	7.95	14.5
		C	120.75	842	4.82	6.85	17
	Rata - Rata Tensile Strength					**7.17**	
3	Al_2O_3 1.5%	A	120.75	911	4.63	7.42	16.9
		B	120.75	896	5.08	7.29	12.5
		C	120.75	1154	5.86	9.40	18.5
	Rata - Rata Tensile Strength					**8.03**	
4	Al_2O_3 2.5%	A	120.75	1184	6.36	9.65	17
		B	120.75	970	5.31	7.90	14.5
		C	120.75	1085	5.65	8.84	15.5
	Rata - Rata Tensile Strength					**8.80**	

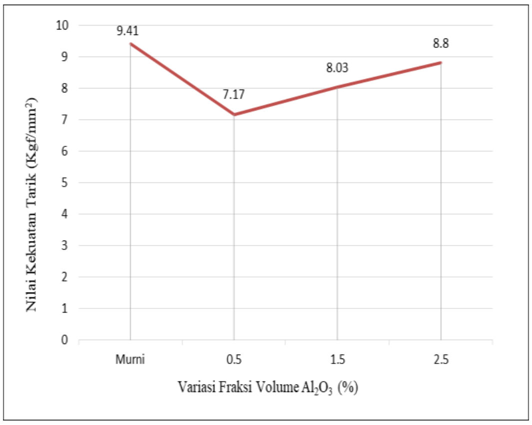

Figure 1 Relationship between Variation of Al2O3 Amplifiers and Tensile Strength Values

Based on Table 2 the tensile test data obtained can be explained through Figure 1 that the increase in the value of the tensile strength starting from the percentage of Al_2O_3 reinforcement particles by 0.5% to 2.5% has increased constantly, but the value of the increase cannot exceed the tensile strength value of pure Aluminum without Al_2O_3 alloy that is equal to 9.41 Kgf / mm^2. In this case it can be stated that the tensile strength value has decreased. The

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decrease in tensile strength is caused by many factors, one of which is found in the Aluminum Matrix Composite (AMC) casting process, starting from the wetting properties of the mixing process of the composition of the Aluminum matrix with Al_2O_3 reinforcing particles which are not good and do not bind to one another. Wettability is the ability of a liquid metal to spread wetting the reinforcing particles. When the process of pouring reinforcing particles into the liquid metal matrix is carried out, air can form on the surface of the reinforcing particles which can cause changes in the surface properties between the particles and the matrix of the liquid metal [2]. As it is known that casting using the stir casting method can overcome the distribution of reinforcing particles which are not uniform / homogeneous, but although they can be spread evenly, the distribution of reinforcing particles can occur unevenly during freezing and the formation of porosity cannot be avoided because at the time liquid metal stirring process in the furnace can cause air bubbles to appear on the surface of the liquid metal, then air can be sucked into the liquid metal castings.

3.2 Hardness Testing

Table 3 Hardness Testing Result Data

No	Variasi Material	Titik Pengujian	Nilai Kekerasan (HRB)
1	Al 1100	1	61.5
		2	51
		3	68
Rata - Rata Nilai Kekerasan (HRB)			**60.167**
2	Al_2O_3 0.5%	1	59
		2	62
		3	64
Rata - Rata Nilai Kekerasan (HRB)			**61.6**
3	Al_2O_3 1.5%	1	63
		2	64
		3	70
Rata - Rata Nilai Kekerasan (HRB)			**65.6**
4	Al_2O_3 2.5%	1	74
		2	80
		3	72
Rata - Rata Nilai Kekerasan (HRB)			**75.3**

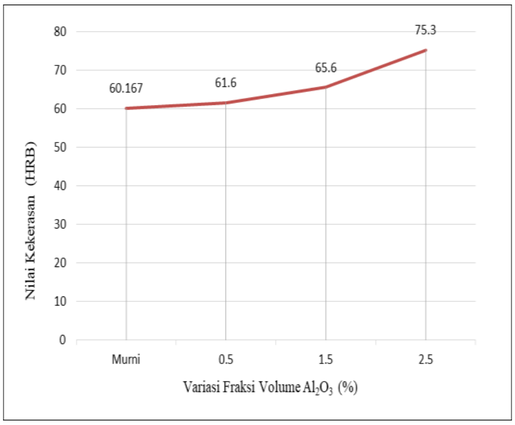

Figure 2 Relationship between Variation of Al_2O_3 Amplifiers and Hardness Values

According to Table 3 the hardness test data, it can be seen through Figure 2 that with the addition of an alumina volume fraction variation (Al_2O_3) of 0.5%; 1.5%; and 2.5% obtained the results of testing a constant increase in hardness. Starting from the first percentage with pure Aluminum content without being given alloy, with a hardness value at this point of 60.16 HRB until the results of the hardness value continue to increase significantly after adding the variation of Al_2O_3 reinforcing particles with a percentage of 0.5%; 1.5%; 2.5%, which is 61.6 HRB, 65.6 HRB, and 75.3 HRB The increase in hardness value in AMC occurs because the reinforcing particles used to improve the mechanical properties of Aluminum composite materials namely alumina (Al_2O_3) are ceramic materials that have high hardness [4]. As a result, the AMC material is strong and can withstand the indented load given to the material when a hardness test is performed. As well as the addition of the element magnesium (Mg) will increase the strength and hardness of Aluminum without too much ductility, the level of hardness of Aluminum alloys is also determined by the percentage of alloy elements added [5].

3.3 Density and Porosity Testing

Table 4 Density and Porosity Test Results Data

Porsentase Al_2O_3 (%)	Massa di Udara (gr)	Massa di Air (gr)	Densitas Teoritis (gr/cm^3)	Densitas Aktual (gr/cm^3)	Persentase Porositas (%)
0%	20.25	7.63	2.68	1.60	0.40
0.5%	22.14	3.32	2.68	1.17	0.56
1.5%	24.8	5.54	2.69	1.28	0.52
2.5%	25.22	6.77	2.69	1.36	0.49

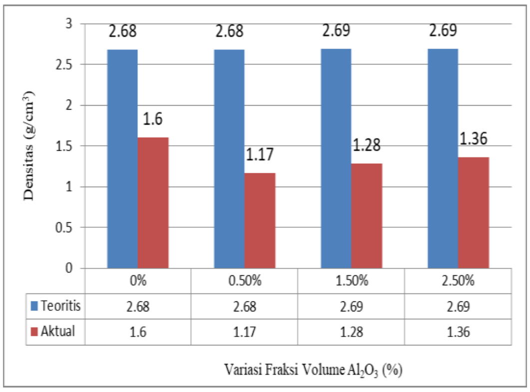

Figure 3 Relationship between Variation of Al2O3 Amplifiers and Density Values

From the results of the comparison between the theoretical and actual density values, the actual density values tend to be lower than the theoretical density as presented in Figure 3. This difference in density values can be caused by the presence of porosity in the actual material, the uneven distribution of Al_2O_3 amplifiers or in the reinforcement area that is not dampened by Aluminum [6]. The decrease in density is due to the addition of Al_2O_3 reinforcing particles to Aluminum which has a bad bond, poor bonding between Al_2O_3 particles and Aluminum causes porosity which also decreases the density of the composite [7].

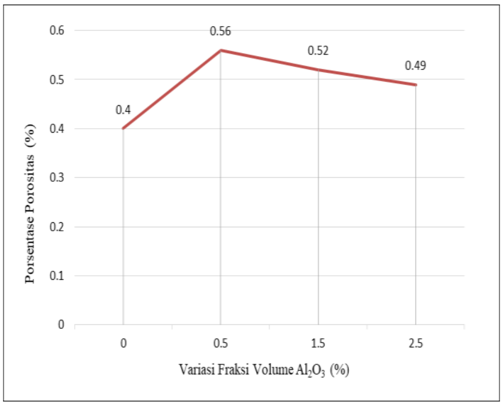

Figure 4 Relationship between Variations of Al_2O_3 Amplifiers to Total Percentage of Porosity

According to Figure 4, it can be seen that the porosity percentage values on Aluminum matrix composites obtained non-constant results. In the first percentage before being given on Al_2O_3, the porosity value is 0.40%. After being given the addition of Al_2O_3 by 0.5%, the value of porosity has increased by 0.56%, but on the addition of Al_2O_3 amplifiers 1.5% and 2.5%, the value of the porosity percentage has decreased again by 0.52% and 0.49%. In this case the porosity percentage is inversely proportional to the value of the tensile strength and the actual density contained in the Aluminum matrix composite, can be seen in Table 5.

Table 5 Comparison of density and porosity measurements with tensile strength

Porsentase Al_2O_3 (%)	Kekuatan Tarik (Kgf/mm^2)	Densitas Aktual (gr/cm^3)	Persentase Porositas (%)
0%	9.41	1.60	0.40
0.5%	7.17	1.17	0.56
1.5%	8.03	1.28	0.52
2.5%	8.80	1.36	0.49

The relationship between the actual density value and the percentage level of porosity is shown in Table 5 where the results are also similar. That the density value is inversely proportional to porosity, because the higher the density, the porosity will be lower and vice versa, if the density value is low then the porosity percentage will be higher. The porosity in the results of the casting stir casting has the potential to occur. This is in accordance with the research of Hashim et al which states that the stir casting process causes chemical reactions between the reinforcing particles and the matrix which will produce gas, and the gas trapped during the stirring process causes porosity and decreases mechanical properties [8]. According to Lin et al, addition of Mg can reduce the porosity [9]. With the presence of Mg as a high wettability, the gap as porosity formed at the matrix interface and the reinforcing particles will be lost or reduced [10].

3.4 Micro Structure Testing

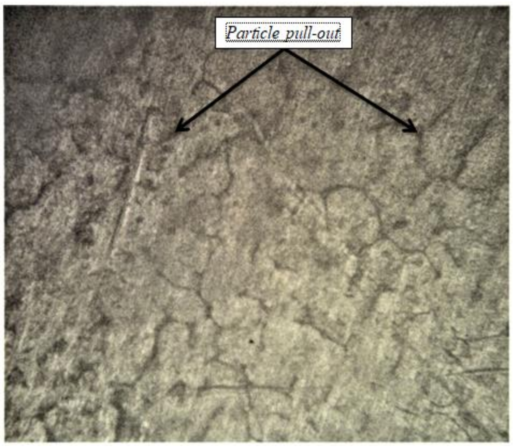

Figure 5 250X Pure Al Micro Structure

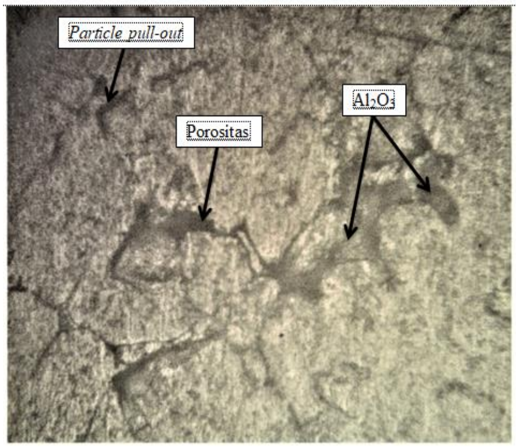

Figure 6 0.5% 250X Al_2O_3 Micro Structure

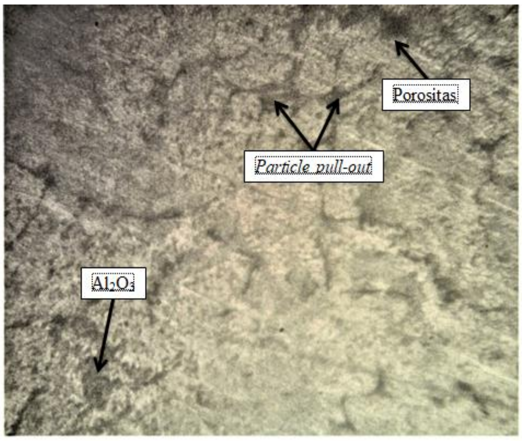

Figure 7 1.5% 250X Al_2O_3 Micro Structure

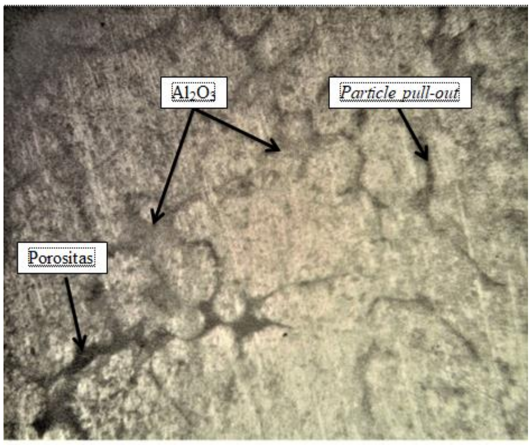

Figure 8 Al_2O_3 2.5% 250X Micro Structure

Based on observations in Figures 5 to 8, it can be seen that the increasing percentage of alumina (Al_2O_3), the dispersion of Al2O3 reinforcing particles is not similar and not well distributed. This is indicated by the lack of grain boundaries between the Aluminum matrix and the reinforcing particles so that more magnesium alloys (Mg) are needed than before. The more magnesium is added, the bond between the matrix and reinforcing particles on the composite becomes better [10]. And in the picture above there are many shaft holes on the surface of the Aluminum matrix composite caused by the pull-out particle which is where the Al_2O_3 reinforcement particles are less well bound to the Aluminum matrix so that the particles can be released and discarded during the sanding and finishing process of the material.

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3.5 Testing Scanning Electron Microscopy

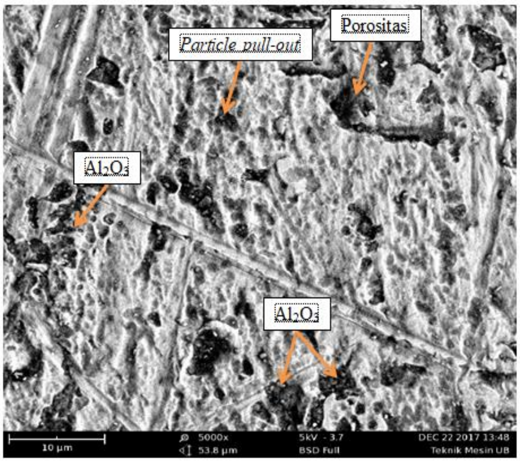

Figure 9 SEM Photo Al2O3 0.5% 5000X

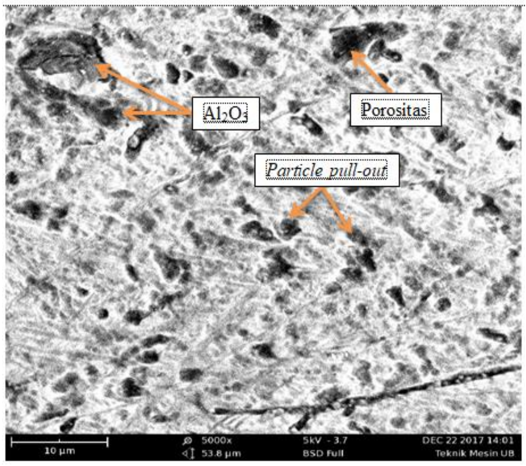

Figure 10 SEM Photos Al_2O_3 1.5% 5000X

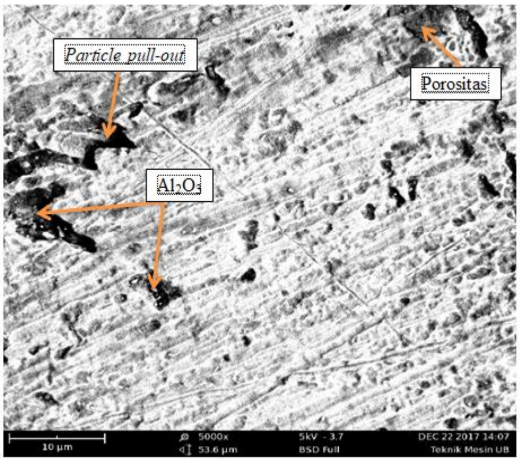

Figure 11 SEM Photos Al_2O_3 2.5% 5000X

Based on the results of observations in Figures 9 to 11, it can be seen that the Scanning Electron Microscopy (SEM) was tested on Aluminum matrix composites with a variation of Al_2O_3 reinforcement variation of 0.5%; 1.5% and 2.5% are proven that with every addition of Al_2O_3 reinforcement particles there is a non-uniform distribution of particles, porosity and particle pull-out. In this case, the tensile strength of Aluminum composite matrix decreases, marked by the lack of grain boundary between the reinforcement and its matrix so that the Al_2O_3 reinforcement particles tend not to fill the Aluminum matrix composite metal perfectly and evenly. It can only be scattered in several parts of the surface of the composite.

4. Conclusion

Based on the results of research on changes in mechanical properties and microstructure of Aluminum matrix composites, using the stir casting method can be concluded as follows:

1. The highest tensile strength value of Aluminum composite matrix is found in pure Aluminum before being given Al_2O_3 alloy with a value of 9.41 Kgf / mm^2.
2. The highest hardness value at the addition of 2.5% Al_2O_3 is 75.3 HRB with a percentage increase of 25% from the lowest hardness value found in pure Aluminum before being given Al_2O_3 alloy that is 60.61 HRB.
3. The lowest percentage of porosity is found in pure Aluminum before being given Al_2O_3 alloy is 0.40% and the highest percentage of porosity is found in Aluminum which after being given Al_2O_3 alloy is 0.5%, with a percentage of 0.56% porosity.
4. From the test results which have been obtained the value of tensile strength decreases due to the casting process which cannot be maximized, starting from poor wetting properties, particles are not evenly distributed until the formation of porosity that cannot be avoided. However, the hardness value of Aluminum matrix composites is constantly increasing, along with the increasing variation of the Al2O3 amplifier added. And the selection of Al2O3 reinforcement particles and Mg alloys are appropriate, where Al2O3 is a ceramic material that has a high hardness.

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