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THE EFFECT OF Mg ADDING IN RECYCLED ALUMINUM CASTING ON TENSILE STRENGTH AND MICROSTRUCTURE

[1,2,3,4,5] Mechanical Engineering Department, State Polytechnic of Malang, Jl. Soekarno-Hatta 9, Malang 65141, Indonesia

Correponding email [1] :
syamsul.hadi@polinema.ac.id

Syamsul Hadi [1], Ahmad Hailala Nur Aziz [2], Pipit Wahyu Nugroho [3], Muhammad Akhlis Rizza [4], Hangga Wicaksono [5]

Abstract. The problems faced are aluminum (Al) waste from industries that damage the environment and scarcity of Al raw materials that need to be recycled from used Al. The research objective was to determine the effect of adding magnesium (Mg) to used Al casting on the tensile strength and microstructure and to determine the comparison of the tensile strength of the Al material used by the piston to the brake lining and drum of motorcycles. The research method includes casting Al used pistons, brake lining and drum, testing the tensile strength and microstructure due to the addition of 0.1; 0.2; 0.5 and 1.0% by weight Mg to the tensile strength and microstructure. The results showed that the addition of Mg 0.5% by weight could increase the tensile strength of 92.96% from 71 MPa to 137 MPa for brake lining as the optimum value which further decreased the tensile strength by 19.7% at the addition of 1% Mg to 110 MPa. Drum material also experienced an increase in tensile strength of 33.71% from 89 MPa to 119 MPa as the optimum value where the tensile strength decreased by 5.88% for the addition of 1% Mg to 112 MPa. The two values of the tensile strength of the brake lining and drum components are lower than those of the piston component valued at 147 MPa, and with the addition of Mg, Mg_2Si is formed which can reduce the porosity of the microstructure, thereby increasing its strength.

Keywords : used aluminum, aluminum casting , microstructure, tensile strength, hardness value, motorcycle pistons, motorcycle brake linings, motorcycle drum

1. INTRODUCTION

The increasing use of Al in the industrial sector results in its waste having a bad impact on the environment, so it is necessary to do recycling to tackle Al waste, scarcity of raw materials, and save more natural resources. Many automotive components are made of Al alloys, including pistons, engine blocks, cylinder heads, valves and so on.

Several related studies have been conducted to determine the effect of chemical elements on the physical properties of aluminum and its microstructure.

The use of recycled aluminum can save at least 5% of the energy required for primary aluminum production, and high-quality casting depends on chemical elements, both on the quality of the melt and the casting process [1]. Si combines with Mg to form a hardening phase of Mg_2Si which can increase strength [2]. The tensile strength and elongation of Al-10Si-2.5Cu-0.8Fe alloy increase first, then decreases with the increase in Mg content where at 1.38% Mg content, the tensile strength of the alloy reaches a maximum of 289 MPa with an elongation of 2.24% and the grain size decreased from 19.8 µm with a content of 0.18% Mg to 11.3 µm at 1.38% Mg [3]. The addition of Mg (0, 5, 10, 15%) to the Al-Si alloy obtained the highest average hardness number at the addition of 15% Mg of 95.44 HB [4]. High Pressure Die Casting (HPDC) on waste aluminum with the addition of 0, 2, and 3% weight of Mg elements produces a microstructure with Mg_2Si precipitates which indicates porosity in the chassis product [5]. The addition of Mg to the used Al-Si alloy wheels cast by the lost foam casting (LFC) method affects the microstructure to be evenly distributed and the formation of Mg_2Si intermetallic compounds which improve its mechanical properties [6]. Added Mg of 1, 1.5, 2 and 2.5 % to the Al-SiO_2 composite with SiO_2 mass fraction of 9% with stir casting method showed the results of SiO_2 uniform distribution along with the addition of Mg [7]. The more Mg is added to the Al-Si alloy, the more its phase tends to form flakes and the grain size becomes denser and homogeneous [8]. The recycled tensile strength of used aluminum from 1st, 2nd, and 3rd stage motorcycle pistons is decreased by 191, 118, and 117 MPa respectively; shrinkage from the 2nd recycled casting compared to the 3rd recycling was 25 and 33% smaller, and the elements lost during the 1st, 2nd, and 3rd recycling were Si, Cu, and Fe [9]. The main problem of aluminum recycling practice is the control of chemical composition for alloy quality [10]. The eutectic temperature can decrease by about 10ºC in increments of 0.8 wt.% Mg [11]. The addition of Mg, Cu, Ag, Ni, Zn, and Sr increased the TS (tensile strength) and YS (yield strength) values, but the % elongation value decreased in base alloy 413.0 after heat treatment at 510ºC for 8 hours [12]. The specific impact strength of the scrap piston with an addition of 15% Mg is 0.035 J/mm^2 which is an increase of 66% from 0.021 J/mm^2 without the addition of Mg [13]. Aluminum recasting causes high porosity with 43.22% for 43 g clusters, 41.85% for 48 g, and 40.55% for 49 g clusters where aluminum has never been used for construction materials, but can be used to inhibit corrosion by coatings on other metals [14].

2. METHODS

2.1 Aluminum Casting

The stages of casting carried out on the tensile test specimen are as follows:

1) Preparation of equipment for melting furnaces, LPG fuel, moulds, and Al materials from pistons, brake linings and drum of motorcycle,
2) Put the used Al and Mg materials into the furnace when they reach a temperature of 660 °C.
3) Pouring Aluminum liquid at a pouring temperature of 720 °C into the prepared specimen mould,
4) Remove the specimen from the mould,
5) Finishing each cast according to the standard dimensions of the specimen, and
6) Coding on all specimens.

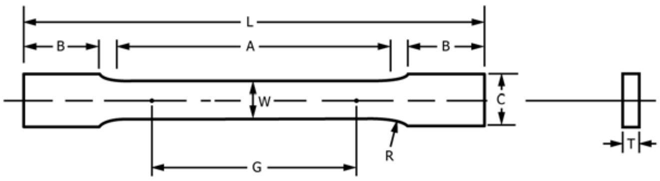
2.2 Composition Testing

The composition of Al castings was tested by X-ray Fluorescent (XRF) shown in Figure 1 for the piston, brake lining and drum materials.

Figure 1. Fluorescent X-ray Equipment

2.3 Tensile Testing

The ASTM E8/E 8M-08 standard specimens used for used Al castings are shown in Figure 2 [15].



Specification: Specimen width (W): 12.5 mm
Gauge length (G): 92 + 0.1 mm
Specimen thickness (T): 10 mm
Fillet radius (R): 12.5 mm
Overall length (L): 200 mm
Clamping length by grips (B): 50 mm
The width of the clamped part of the grips (C): 20 mm

Figure 2. Tensile Test Specimen Standard ASTM E8/E 8M-08 [15]

The tensile test performed with the universal testing machine is shown in Figure 3.

Figure 3. Universal Testing Machine

The tensile strength, σ is calculated by Eq. (1).

$$\boldsymbol{\sigma = F/A_0} \quad (1)$$

where,
σ: Stress (N/mm^2)
F_{max}: Tensile force (N)
A_0: Cross-sectional area of the tensile specimen (mm^2)

2.4 Hardness Testing

The hardness test was carried out using the Vickers microhardness tester is shown in Figure 4.

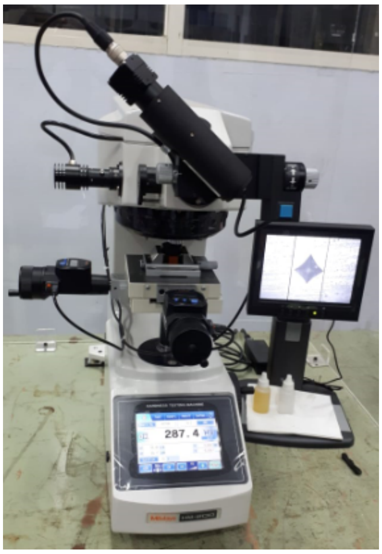


Figure 4. Microhardness testing machine

2.5 Observation of microstructure

The microstructure was prepared metallographically starting from cutting the specimen, mounting the specimen handle, grinding, polishing, etching and observing with an optical microscope.

3. RESULTS AND DISCUSSION

3.1 Composition Test Results

The results of the composition test contained in the used Al castings are shown in Table 1.

Table 1. Composition Test Results of used Aluminum Castings

Piston		Brake lining		Drum	
Element	(%)	Element	(%)	Element	(%)
Mg	0.2	Mg	0.09	Mg	-
Al	60.1	Al	64.0	Al	62.8
Si	15.9	Si	12.8	Si	13.2
P	0.4	P	0.46	P	0.46
Ca	1.3	Ca	1.64	Ca	1.94
Ti	0.08	Ti	0.11	Ti	0.09
Cr	0.53	Cr	0.53	Cr	0.70
Mn	3.8	Mn	6.3	Mn	4.9
Br	15.1	Br	12	Br	14.2
Zr	0.37	Zr	0.56	Zr	0.41
Ba	1.1	Ba	1.4	Ba	1.4
Pr	0.96				

3.2 Tensile Test Results

The tensile test of the used Al castings before and after the addition of Mg is shown in Table 2.

Table 2.Data of Tensile Test Results (in MPa)

No.	Used Al	Replication	Adding of Mg (%)			
			0	0.1-0.2	0.5	1
1	Piston	1	146.46			
		2	142.02			
		3	153.22			
	Average		**147.23**			
2	Break lining	1	60.49	141.50	121.05	115.91
		2	79.16	137.28	156.36	93.22
		3	73.12	81.14	134.52	120.51
	Average		**70.92**	**119.97**	**137.31**	**109.88**
3	Drum	1	81.06	130.27	129.68	100.85
		2	104.31	98.05	114.21	123.32
		3	81.78	98.97	113.51	112.09
	Average		**89.05**	**109.10**	**119.13**	**112.09**

3.3 Hardness Test Results

The results of the hardness test of the used Al castings before and after the addition of Mg with the Micro Hardness Testing Machine with specimen dimensions of 20x14x10 mm are shown in Table 3.

Table 3. Hardness Test Result Data (in HV)

No.	Used Al	Replication	Adding of Mg (%)			
			0	0.1 - 0.2	0.5	1
1	Piston	1	114.2			
		2	115.4			
		3	116.3			
	Average		**115.3**			
2	Brake lining	1	101.5	108.3	115.1	106.5
		2	105.2	109.6	112.1	110.4
		3	93.9	113.0	114.4	107.6
	Average		100.2	110.3	**113.9**	108.2
3	Drum	1	101.7	106.4	115.8	101.6
		2	96.4	105.2	120.9	102.7
		3	99.8	100.7	122.1	108.2
	Average		99.3	104.1	**119.6**	104.2

3.4 Results of microstructure observations

The results of the microstructure observation are shown in Figures 5 to 9.

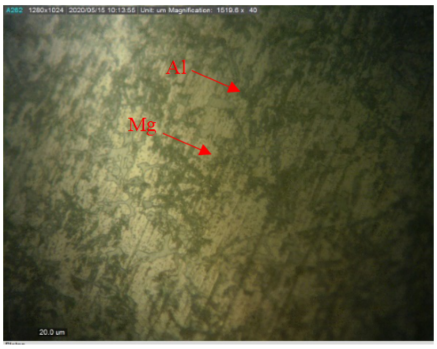


Figure 5. The Microstructure of Used Piston Castings (1500x)

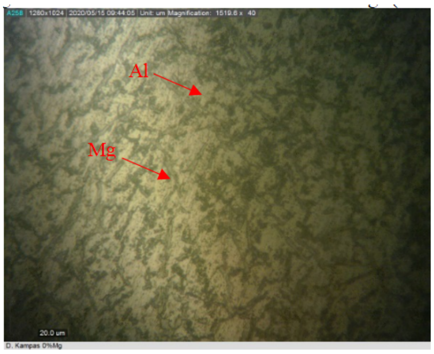


Figure 6. The Microstructure of Used Brake Lining Castings with 0% Mg (1500x)

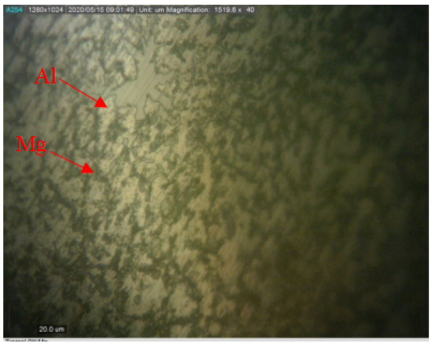


Figure 7. The Microstructure of Used Drum Castings with 0% Mg (1500x)

Figure 8. The Microstructure of Used Brake Lining Castings with 0.5% Mg (1500x)

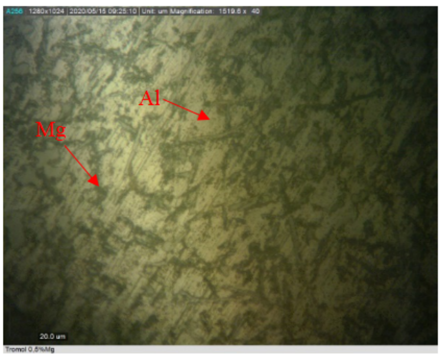


Figure 9. The Microstructure of Used Drum Castings with 0.5% Mg (1500x)

3.2 Discussion

The piston's tensile strength has a higher value of 147 MPa compared to the brake lining and drum of motorcycles. The tensile strength value of the brake lining and drum of motorcycles increases with the addition of Mg elements from 0 to 0.5% but decreases for the addition of 1% Mg which means that the optimum value of adding Mg is 0.5% is shown in Figure 10.

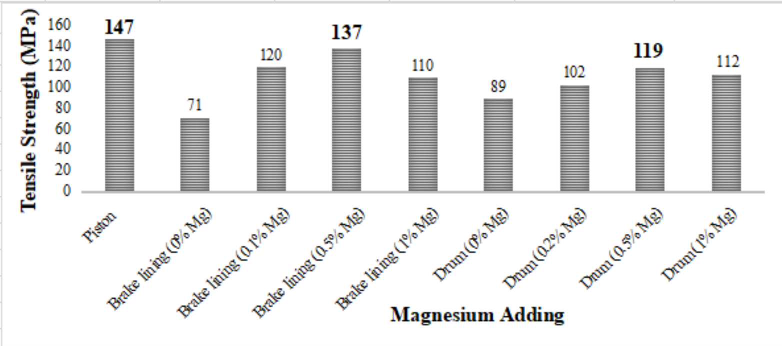


Figure 10. Comparison of tensile strength in used Aluminum castings

Figure 10 shows that the addition of 0.5% Mg to the brake lining and drum castings increases the tensile strength to close to the piston strength at 137 MPa for the brake lining castings and at 119 MPa for drum materials.

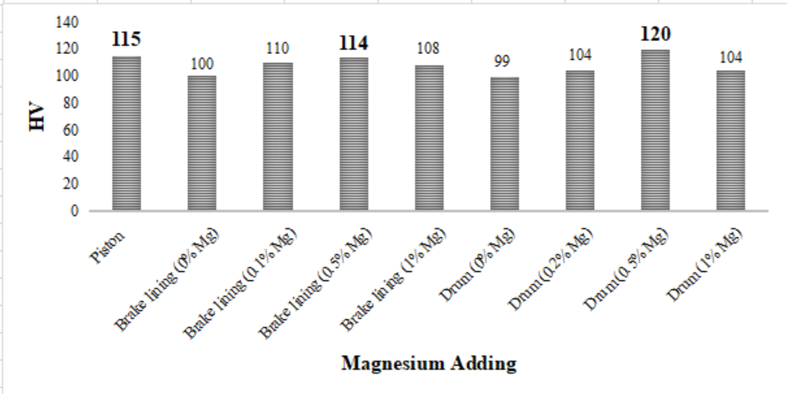


Figure 11. Diagram of comparison of hardness values in used Aluminum castings

Figure 11 shows that the addition of 0.5% Mg to the brake lining and drum castings increases the hardness value. In the cast, the brake lining rises to 114 HV, close to the hardness of the piston, while in the drum material it increases to 120 HV, which exceeds the hardness value of the piston which is possible because Mg has reached 0.7% and the Cr content is higher than the piston and brake lining.

From the results of microstructure photos before and after the addition of the Mg element to the castings of brake lining and drum, it shows a change in the shape of the microstructure because: (a) At 0% Mg, it can be seen that the grain structure is loosely arranged, the distance between the grains is quite far apart, and (b) At 0.1% and 0.5% Mg the shape of the structure tends to be smaller and denser so that the strength increases.

The addition of the Mg element to the brake lining and drums castings makes the phase shape tend to form slender flakes, then the shape and grain size becomes denser and homogeneous which affects the tensile strength and hardness value. The addition of Mg element can result in the formation of a lot of Mg_2Si precipitates which can close the space in the increasingly dense alloy.

The tensile strength of certain types of motorcycle aluminum pistons for the first, second and third recycling decreases from 376 MPa to 191 MPa, and continues to 118 MPa, because Cu, Si and Fe elements cannot melt with LPG fuel [16], while addition Mg up to 0.5% increases the tensile strength, meaning that in the recycling there is an simultaneous increase and decrease in competitive tensile strength.

4. CONCLUSION

The conclusions from the research results are obtained as follows:

1) The results of the tensile test show that the tensile strength of the piston castings specimen is 147 MPa. The highest tensile strength was in the brake lining cast specimens valued at 137 MPa and drum castings valued at 119 MPa in the addition of 0.5% Mg.
2) The results of the hardness test show that the hardness value of the piston castings specimen is 115 HV. The highest hardness value was found in the brake lining cast specimens valued at 114 HV and drum castings valued at 120 HV with the addition of 0.5% Mg. The value of drum hardness is higher than the piston is possible because the Mg content reaches 0.7% and the Cr drum composition is higher than that of the piston.
3) The addition of Mg to the brake lining and drum castings has a significant effect on the addition of 0.5% Mg which increases the tensile strength of the two materials due to the formation of Mg_2Si precipitates which can

cover the empty spaces in the alloy structure, causing the structure to be tighter and more homogeneous, but has decreased in 1% Mg increments.

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