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Influence of Magnesium on Hardness and Microstructure of ADC 12 Alloy Produced by Gravity Casting Method

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Abstract. Magnesium addition produce modification level of silicon's eutectic for Al-Si-Mg. An increase in magnesium content will increase mechanical properties value of ADC 12 alloy. Highest hardness value reached when Mg content is over 4%. Properties of material's increased because Mg that added to the alloy will bind with Si and form Mg_2Si compound. Where the Mg_2Si compound will close the empty space in crystal structure of Al-Si-Mg and the distance between the grain is getting closer so that ADC 12 alloy possess improved strength and hardness. ADC 12 alloy with the addition of 8% magnesium variation will have the highest hardness value, which is 143.44 BHN

Introduction

Aluminum was first discovered as an element in 1809 by Sir Humphrey Davy Aluminum. Paul Heroult of France and Charles Martin Hall of Ohio acquired aluminum metal from alumina by electrolyte In 1886 [1]. Aluminum has such a wide application in engineering due to its mild density and good corrosion resistance [2]. Other important properties of aluminum are low aluminum density, good thermal and electrical conductivity [3]. In the future, the use of aluminum is expected to be widely open, both as the main material and as a supporting material with the availability of aluminum seeds in the abundant earth.

According to Surdia and Saito (2000), the alloying elements used to improve the mechanical properties of aluminum without heat treatment include silicon (Si), magnesium (Mg), and manganese (Mn). But on the element Mn has a maximum solubility rate of 1.82% at a temperature of 500^0C. Al-Si Alloy has good mechanical properties is high tensile strength and toughness. The properties of Al-Si alloys are particularly influenced by the morphology and size of silicon particles [4]. According to Setia et al, (2016) the addition of magnesium elements will increase the strength and hardness of aluminum without decreasing its ductility. The magnitude of added magnesium elements will also affect the micro structure of the castings [5].

The purpose of adding magnesium to the Al-Si alloy is to improve the mechanical properties of Al-Si. The increase in mechanical properties occurs due to the formation of Mg_2Si compounds in aluminum alloys, wherein the Mg_2Si compound fills the empty space within the Al-Si crystal structure so that Al-Si alloys have short inter grain spacing [6].

Some researchers claim that the addition of magnesium will improve the mechanical properties of the material. An increase in mechanical properties occurs due to an increase in modification of silicone eutectic on aluminum Al-Si-Mg alloys. The effect of modifying eutectic silicon will decrease with the addition of magnesium higher than 1 wt.% [7]. Yildirim and Ozyurek, (2013) suggest that with the increase in linear magnesium addition can increase porosity.

The gravity casting method by using a permanent mold will produce parts that have finer microstructure with smaller pores so as to improve its mechanical properties [8]. The advantage of the gravity casting method is that it can be cast on complex component parts especially for thick wall sections, such as cylinder heads [9].

The research was conducted for the development of aluminum alloy ADC 12 with magnesium addition of 2 wt%, 4wt%, 6% wt and 8% wt. The method of casting in this research is using gravity casting method. The purpose of this study was to produce an aluminum alloy of ADC 12 which has improved mechanical properties.

Experimental Method

In experimental studies, Al-Si ingot were cut to size (5 x 2 x 1) cm. The while Mg was added to molten Al various from 2 wt%, 4wt%, 6%wt to 8%wt. Melting processes of material were carried out in an electric furnace. Casting process is gravity casting method. The melting process including degasing process was carry out by injecting argon gas into liquid metal for 5 min at 1 bar pressure and 750 ºC in a graphite crucible of 3 kg capacity using a melting furnace. The figure of casting process is shown in Fig. 1

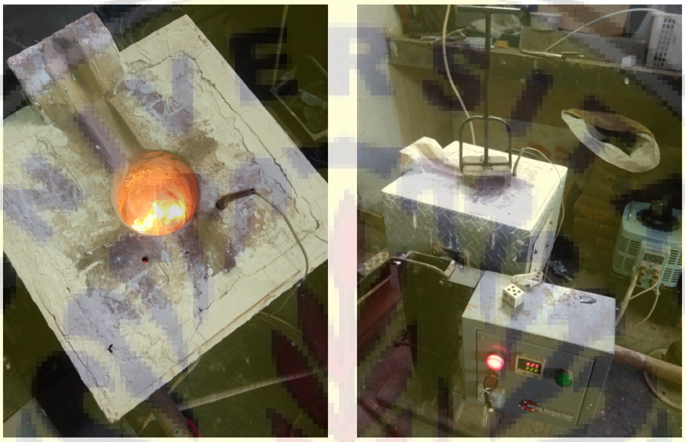


Fig. 1 Casting process in electical furnace

Then Mg ingots were poured into the molten Al. Following the melting and degasing processes were completed, the molten material was poured into the mold.

Hardness test was performed using *Hardness Tester TH120B*, according to ASTME 10-01. Microstructure of material was observed using with optical microscope (*Microscope Olympus BX41M*). The etching solution used was HF 5%. This test was performed to discover the phase content that formed on specimen.

Result and Discussion

Hardness, From hardness test data, with inducing the amount magnesium (0%, 2%, 4%, 6%, and 8%) From figure 2, it is seen that hardness of ADC 12 alloy increased with the addition of magnesium an increase in hardness is affected by the increment of magnesium addition toward ADC 12 alloy. It is related with the grain size of aluminum, as the grain size of aluminum become smaller, the density of the aluminum is getting closer, thus the alloy become more hard. Aluminum with the addition of magnesium in the amount of 8% possess the highest value for hardness, which is 143.44 BHN.

The same result showed by Cholis et al, 2013, the hardness value of aluminum increase with the addition of magnesium [10]. It is related with the smaller aluminum grain's size. Small aluminum grain size will make the distance of the grain more closed and dense, thus the alloy become harder [11]. Hardness increment on all variation addition of magnesium are caused by the influence of grain refiner and magnesium particle which form Mg_2Si phase, thus the compound will close the empty space in crystal structure so the alloy have close packed distance between grain crystal. Hwang et al, 2009 [12], using aluminum type 319 with the magnesium addition showing the same result, which is an increase in magnesium addition can increase mechanical properties.

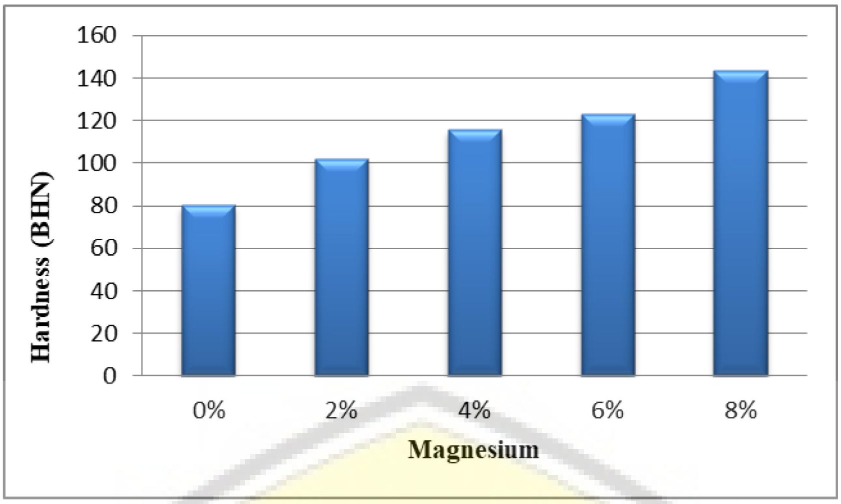
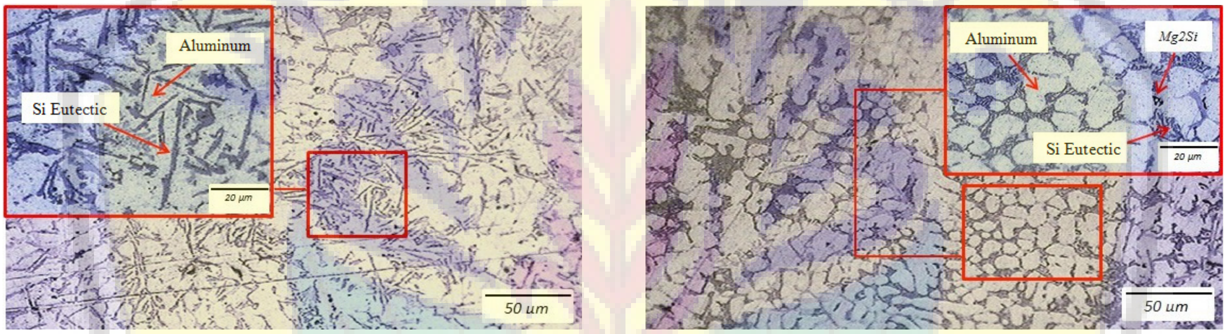


Fig. 2 Value for hardness ADC 12 with the addition of magnesium

Microstructure. Microstructure observation on ADC12 alloy which contain 0% and 2% magnesium content can be seen at Fig. 3 below.



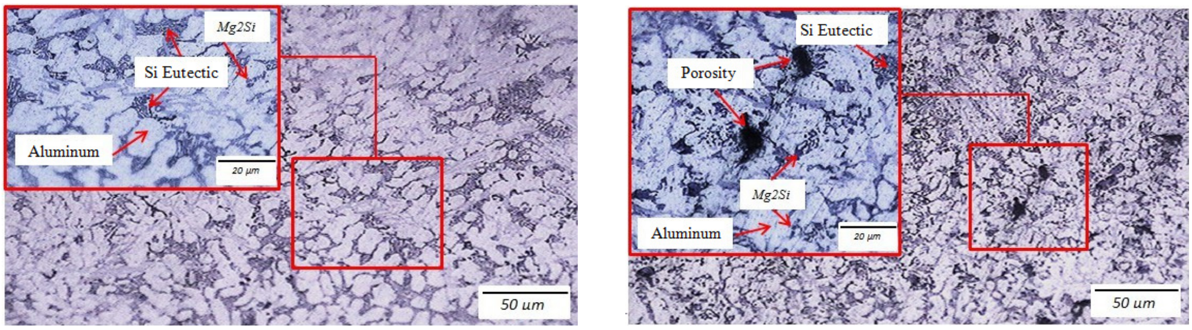
(a) (b)

Fig. 3 Microstructure of ADC 12 alloy with (a) 0%Mg, (b) 2% Mg

Fig. 3 (a), shows microstructure of ADC 12 alloy without magnesium addition. Microstructure consist of aluminum phase with bright white colour and Si eutectic with needle like and coarse with the colour of dark. From Figure 3, it can be seen that dendritic structure is surrounded by the coarse silicon eutectic. This because the absence of grain growth constraint, so that the microstructure of this alloy seems irregullar. This Si eutectic's unsure that make Al-Si alloy possess high ductility.

On Fig. 3 (b), shows microstructure of ADC 12 alloy with the addition of 2% magnesium content. From Fig. 3 (b), can be known that with the addition of 2% magnesium content will change the grain shape of α aluminum. This happens because Si will bind with magnesium and form Mg_2Si compound. Mg_2Si compound will close the empty space in the crystal structure, so the alloy has a closer distance between the crystal grain. It also simillar with Salleh. M. S, et al, 2015 [6], research, magnesium addition in aluminum alloy will increase its mechanical properties through the forming of Mg_2Si compound as cast alloy. The original ADC12 alloy consists of a higher fraction of coarse grains compared to Al_2Ca-added ADC12 with 0.6% Mg and Al_2Ca-added ADC12 with 0.8% Mg alloy. A noticeable change in the morphology of eutectic Si was observed when the Mg content increased from 0.6 to 0.8 wt%, during which the eutectic Si structure changed from acicular to fine lamellar. Similarly, the mean shape factors for as-cast Al_2Ca-added ADC12 with 0.6% Mg alloy (3.91). The eutectic Si in the as-cast Al_2Ca-added ADC12 with 0.8% Mg alloy had a mean shape factor of 3.89 [13].

Thus the mechanical properties of both tensile strength and hardness is increased. Same case with the 4% magnesium variation as shown on Fig. 4 below.



(a) (b)

Fig. 4. Microstructure of ADC 12 alloy with (a) 4%Mg, (b) 6% Mg

On Fig. 4, it can be seen that magnesium particle is absence inside Al-Si matrix that binds with silicon and form Mg_2Si compound. With the addition of 4% magnesium content will cause the grain size become more closer and an increased Mg_2Si phase form. This will increase tensile strength of aluminum alloy.

From Fig. 5, it can be known that with the addition of magnesium content can reduce the size of primary aluminum grain. But with an increase of magnesium also increase porosity of ADC 12 alloy. This is the reduction factor of tensile strength on ADC12 alloy. X. Jiang et al, 2011 [14], reveal that the magnesium particle which form Mg_2Si phase can obstruct the grain disclocation's movement so it can increase mechanical strength. Whilst the decreasing of tensile strength is caused by the greater amount of Mg_2Si compound in aluminum alloy which turn its ductility into lower level and more brittle.

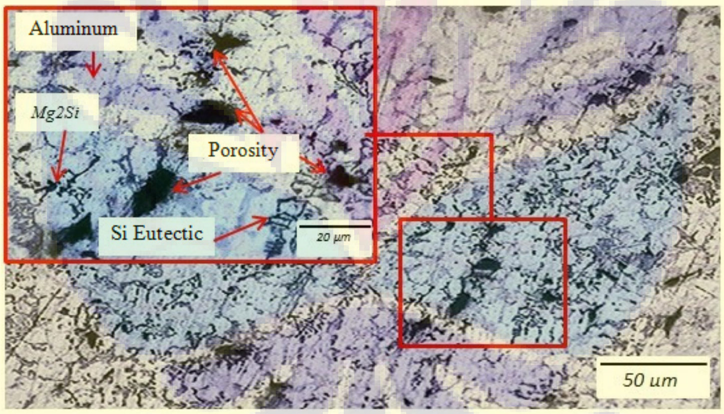


Fig 5. Microstructure of ADC 12 alloy with 8%Mg

In Fig. 5, it is seen that porosity will increase with increasing Mg content used in this casting. This happens because magnesium is highly reactive to oxygen during the melting process. So it will increase the Mg that binds with oxygen. During melting, degassing is required inside molten aluminum to reduce oxygen dissolution inside molten aluminum. Porosity is caused by trapped gas inside molten aluminum and high hydrogen solubility when the aluminum is in liquid state. Bozchaloei et al, 2012 [15], on his research append that porosity is the main cause of lowering the tensile strength in Al-7%Si-Mg alloy.

Summary

From this research, the following conclusion were drawn

1. The Highest hardness on aluminum ADC12 was obtained on 8% magnesium with a value of 143.44 BHN, while for the 2% magnesium variation the hardness value was the lowest with the hardness value of 102.11 BHN.
2. The increased Mg content in the ADC 12 alloy increases the hardness value of the ADC 12 alloy, but this will decrease the other mechanical properties.

3. Porosity occurring at 8% Mg caused by magnesium is very reactive to oxygen during the melting process, so the more magnesium is added the more oxygen attached to the alloy of ADC 12.
4. Grain size became more fine along with the addition of magnesium, however with the addition of 6% and 8% magnesium would increase porosity thus it also reduce strength of ADC12.

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