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PHYSICAL AND MECHANICAL CHARACTERIZATION OF AL-SI ALLOYS WITH THE ADDITION OF MG AS MATERIAL OF THE CHASSIS MODEL MADE BY THE HIGH-PRESSURE DIE-CASTING (HPDC)

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ABSTRACT

Aluminium alloys have been developed for the automotive material, especially in the chassis structure. One of the development of aluminum alloy focuses on the system of Al-Mg-Si. This paper presents results on a manufacturing chassis car model made by Al-Si alloys with variety of magnesium content through the HPDC process. In this study, the selected raw material is ADC12, while HPDC was performed at a constant pressure of 7 MPa. The optimal composition of a super ductile alloy of Al-Mg-Si was related to the Mg variation in wt.%; 0, 3, 4 and 5 and the pouring temperature of 750 ^{O}C. The heat treatment was performed at the age hardening treatment at 540 ^{O}C for 60 minutes and artificial aging of 150 ^{O}C for 4 hours. Material characterization includes porosity, hardness testing and micro structure evaluation using an optical microscope. The measured data of porosity, hardness, tensile strength were compared to that of standard data for automotive chassis material. It shows that the measured hardness met the required standard of automotive material.

Keywords: Aluminium alloy; HPDC; Magnesium; Chassis model; Heat treatment

1. INTRODUCTION

In an effort to improve the economy in fuel consumption and reduce harmful exhaust emissions for public transport, the weight reduction of vehicle through the use of lightweight metal is one of the ultimate goal in the automotive industry [1]. In this case, the use of aluminum alloys has been beneficial and good opportunities to reduce vehicle weight, while the development of the automotive industry for the long term is still limited to the field of environmental protection [2-3]. During this time, the automotive industry has been using a variety of aluminum components for electric trains and chassis components, including transmissions house, cylinder heads, inlet manifold, stagnant pools of machines, wheel rim, as well as for decorative tram products [4]. The tendency of the automotive industry using aluminum as a lightweight substitute for steel components has made the alloy consumption rise sharply. One of the significant increase in the consumption aluminum can be found for car body structure [5-6].

The use of aluminum, both wrought and cast aluminum alloys, is found extensively in many parts such as automotive framework, in particular to the scope of the framework design of the engine and passenger cars in order to design [1,6,7,8]. The mechanical properties of aluminum alloys has reached a yield strength of 124-240 MPa and a maximum tensile strength results of 220-317 MPa and elongation of 10-30%. Some aluminum alloys are typically used for external accessories components which have excellent characteristics in terms of hardenability. The yield strength of aluminum alloys can be currently increased to 60 % after the hardening process. To maximize the benefits of the heat treatment process can be commonly found in the metal molded aluminum alloy for frame structure, because it must have superior mechanical properties comparable to components made by aluminum plate.

On the other hand, the mechanical properties of the aluminium alloy castings available today, [9-10], have been not competitive and not meet the needs of the automotive industry today. In particular, the Al-alloy possessed elongation is not enough for application in manufacturing Industry. To increase the strength of aluminum alloy castings, the wall thickness should be increased. However, a few extra manufacturing steps and tools must be added to improve the quality products. Furthermore, the automotive industry has lack of efficient in achieving the ductility products because of the increased weight of castings and processing costs. Chassis is a framework that serves as the support of heavy vehicles, machinery and passenger. Usually the chassis is made of a steel frame that holds the body and engine of a vehicle. The car's chassis is usually made of steel, but the use of steel lead to high weight product and the need of the research on the light weight of chassis become increasing important. Here material model of chassis made of aluminum-based alloys is proposed. The material must have the strength to bear the weight of the vehicle. The chassis also serves to keep the car remain rigid, rigid and not undergo bending [1]. The purpose of this study was to use the HPDC equipment for making the chassis model with good performance and

a) To produce aluminum alloy components for the model of car chassis with a tensile strength of meeting qualified automotive industry
b) To measure the density, porosity and hardness of materials component of the model car chassis

2. MATERIALS AND METHOD

2.1. Material preparation and equipment

Raw material for die casting is ADC12 bars, which was cut into small piece in order to fit into the crucibles. Initially 1 kg of the pieces ADC12 was weighed and the % weight of magnesium powder (3, 4 and 5 %) was set-up, while LPG gas was selected to melt the Al. The HPDC equipment used for the casting is shown in Figure 2.1. The smelting process was carried out for 12 ADC bars melting at temperature of 700 ^{O}C and subsequently stirred before molding.

2.2. The process of casting

Casting process was taken out at the Laboratory of Physical Metallurgy, Department of Mechanical Engineering using the HPDC foundries. The mixing process of magnesium was done when the temperature reached a temperature of 700 ^{O}C for ADC12 melt. Moreover, the Mg mixing process was carried out at three different weight variations of 3% Mg, 4% Mg, and 5% Mg. Mixing process was performed using a stir casting machine at the rotational speed ± 65 RPM for 2 minutes. The subsequently casting process was conducted on the HPDC machine with a pressure of 7 MPa. Testing casting results were related to whether they are workable or not. Feasibility of the product can be seen from the results of castings product perfection in accordance with the shape of the mold.

2.3. Heat treatment of the casting product and laboratory testing

The casting specimen was then heat-treated with a solution treatment at temperature of 500 ^{O}C for 60 min. and cooled using the water quenching. After that, the test specimen was treated with the artificial aging at temperature of 150 ^{O}C for 4 hours. Eventually the laboratory tests was conducted to determine the properties of the test specimen including density and porosity by Archimedes method.

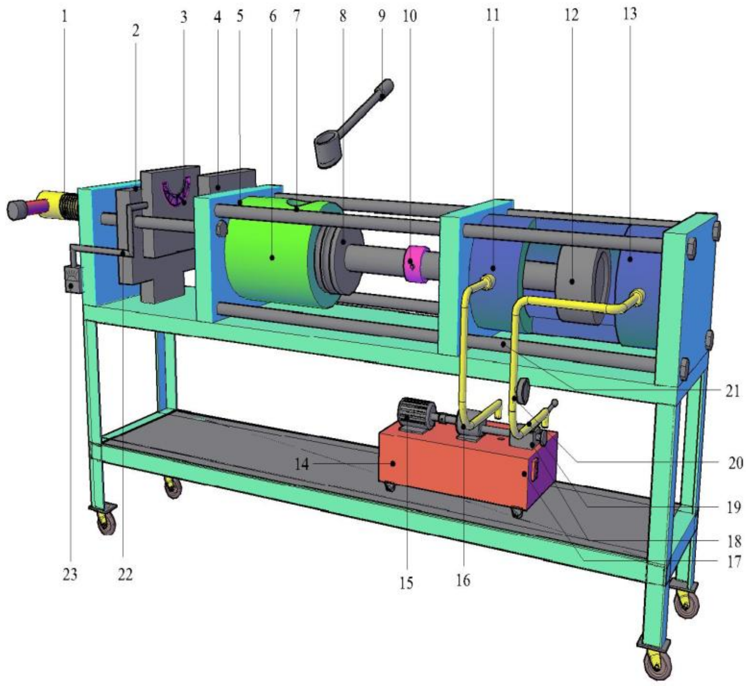

Figure caption

1. Screw of casting clamp
2. Die-casting
3. Cavity of casting
4. Fixed die cast
5. Support of casting
6. Cilinder of casting
7. Inlet of casting
8. Piston
9. Ladel
10. Shaft
11. Hydraulic cylinder
12. Hydraulic piston
13. Supporting shaft
14. Oil container
15. Motor
16. Oil Pump
17. On/OFF
18. Pressure setting
19. Lever of hydraulic piston
20. Measuring pressure
21. Hose oil
22. Thermocouple
23. Temperature digital

Figure 2.1 Model of HPDC used for Al-Si-Mg casting

3. RESULTS AND DISCUSSION

3.1. Chemical composition of ADC12

The raw materials used in this research are Al-Si alloy (ADC12) supplied by PT. Pinjaya Metal Mojokerto, East Java, Indonesia. The chemical composition of the material is presented in Table 3.1. Obviously, the major element is clearly Al and Si. This material can be categorized as hypoeutectic binary alloy, because it is widely accepted that the eutectic reaction takes place at 577 ^{O}C and at a silicon level of 12.6%. Some impurities include Cu, Zn and Fe. In the presence of Cu content (1.81 wt.%), the alloy may exhibit hardenability by the precipitation hardening.

Table 3.1 Chemical composition of ADC 12

MATERIAL (ADC 12)	**Chemical element**	**Composition (wt.%)**
Al10Si	Al	86.13
	Si	10.34
	Cu	1.81
	Zn	0.85
	Fe	0.87

3.2. Density and porosity of the product model chassis

To determine density of chassis model is firstly created three-replica samples with a size of 1 cm x 1 cm. Each sample was made by cutting casting products by identifying the left side (A), middle (B), and the right side (C) (Figure 3.1). Data taken from the measurement results with digital balance produces dry period (M_{dry}) and a wet (M_{wet}). Furthermore, the density of the test object ($\rho_{apparent}$) obtained by the following equation:

$$\rho_{apperent} = \rho_{H2O}\, x\, \frac{M\ dry}{M\ dry - M\ wet}$$

The results of calculated density of alloy Al-Si-Mg with 0% 3%, 4%, and 5% Mg are shown in Figure 3.2. It shows that density of the product decreases at 4% and then increases at 5% of Mg, conversely the porosity increases to 4% according to the comparison value of density and porosity.

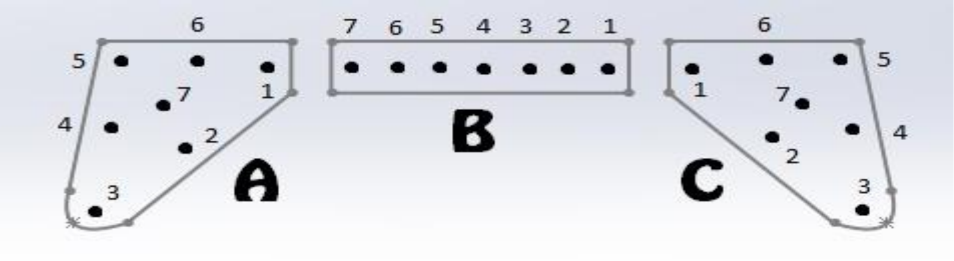

Figure 3.1 Identified sample for density and hardness measurements

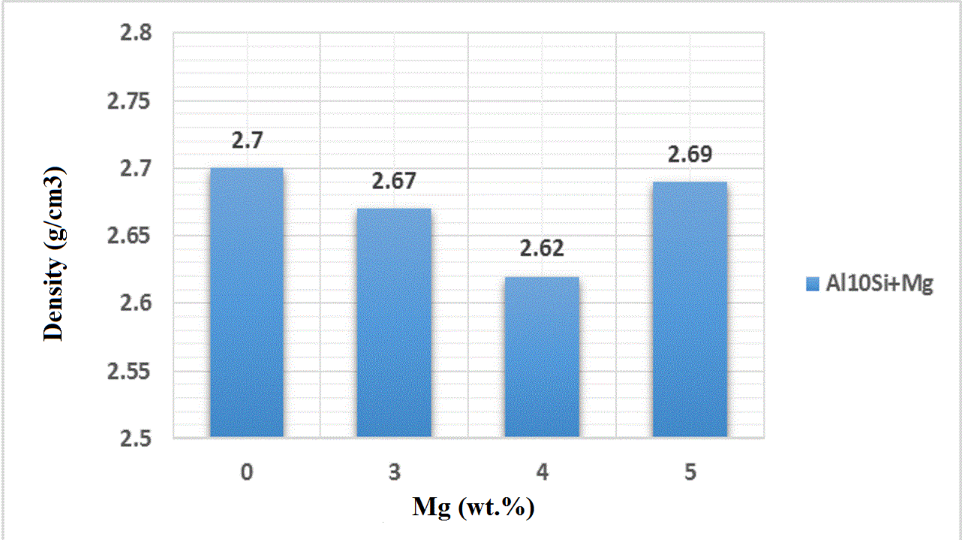

Figure 3.2 Density as a function of Mg-content

3.3. Hardness of the casting product

Hardness test was conducted by Rockwell hardness tester B (HRB) according to the standard ASTM E18-11. The process of selecting and preparing specimens was performed similar to the density of the test specimen. Similarly, the heat-treated samples were prepared in three-replica, as shown in Figure 3.2. Results was presented in Figure 3.3.

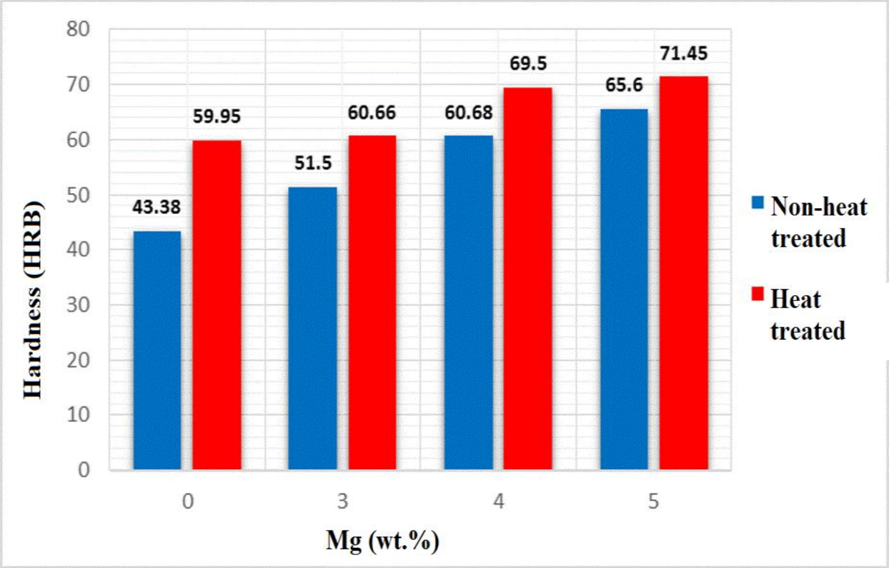

Figure 3.3 Hardness of non-heat treated and heat treated samples

It shows that the chassis model of non-heat treatment has the lower hardness value than that of the heat-treated chassis. Hardness values of chassis model with 5 wt. % Mg experiencing heat treatment has the highest hardness value of 71.45 HRB. This proved that the solution heat treatment and artificial aging lead to the high harness materials. Increasing value of hardness may be caused by the β precipitates in the Al-matrix. Atom - Mg or Si atoms are in the condition of artificial aging will tend to position themselves against the solvent atoms that occur coherence. To precipitates become smaller and the number of precipitate also increased with the distance between the particles. This precipitate which can acts as a barrier causes dislocation increasingly difficult when the deformation of alloys may occur.

4. CONCLUSION

It can be concluded from the results of experiments that

a) Density of the casting product varies with the Mg content of the raw materials.
b) The hardness of the non-heat treated chassis models is lower than the heat treated chassis model. The highest hardness of the model is about 71.45 HRB.
c) The age hardening of chassis models lead to increase the mechanical properties (hardness, tensile strength, and ductility).

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