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ANALYSIS OF STRONTIUM ADDITION ON AL-SI-MG ALUMINUM ALLOYS

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ABSTRACT

The use of metal based materials has high potentials following the development of the automotive industry. It follows the increase of demand in automotive vehicles, machine components, and many more. Aluminum is a type of metal that is of interest in the industry. The lightweight aluminum properties and corrosion resistance make aluminum widely used in various industries. Al-Si-Mg alloy is one alloy that is able to increase the strength of aluminium. The purpose of this study is to understand the addition of strontium modifiers and the expected improvement of mechanical properties of Al-Si-Mg alloys. The addition of strontium, in general, is able to change the shape of eutectic silicon particles from the form of acicular particles into finer shapes. The results showed that the addition of strontium modifiers in Al-Si-Mg alloys was able to increase tensile strength and hardness. The results of the observation of the microstructure were found to change the shape of eutectic silicon particles with the addition of a strontium modifier. The addition of strontium found the micro-change of eutectic acicular silicon structure to fibrous in the Al-Si-Mg alloy.

Keywords: aluminum, hardness test, tensile test, gravity casting, strontium, microstructure.

1. INTRODUCTION

Silicon is an element added to Al alloys to improve or increase wear resistance of the material. Al-Si alloy properties have high fluidity, low shrinkage and low thermal expansion coefficient. The Al-Si alloy's properties are influenced by the morphology and size of the silicon particles [1]. The Mg is the basic element that gives strength and hardness in this alloy [2]. Al-Si-Mg with high Mg content is a lightweight material that is important in the industrial applications because it has a low density and good wear resistance [3]. This could impact its weight, where Al-Si-Mg alloy is often used in the aerospace indsutry. Strontium, sodium, and antimony are elements that are often used to modify the microstructure of alloys, in this case the microstructure of Si. Strontium is added to modify the eutectic phase and Si shape of the rough acicular into a finer and rounder fibrous form [4].

2. MATERIALS AND METHODS

2.1 Aluminum

Aluminum is widely used as a metal casting industry material. Aluminum is a non-ferrous metal where in its application, it has several strength disadvantages so that pure aluminum cannot be used as a construction material. Obtaining other properties for aluminum can be done by mixing or alloying with other metal elements such as: copper, manganese, magnesium, silicon and others according to the specific properties that are desired.

Pure aluminum has good casting properties but has poor mechanical properties. Therefore, an alloying with other elements to improve the mechanical properties is often performed. Such an alloy is of magnesium and aluminum which has good corrosion resistance properties. The addition of magensium in this alloy will also increase strength, hardness and ductility better than pure aluminum. Al-Mg alloys with Magnesium concentrations of more than 11% are either used or applied to structural components in the automotive and aerospace industries due to their low density and compressive strength [5]. Other properties of Al-Si alloys is that they have high fluidity, low shrinkage and low coefficient of thermal expansion. The increase of its mechanical properties can be done by modifying the structure at the cooling phase. The addition of certain elements can cause a transition from microstructure, so as to improve its mechanical properties [6].

This magnesium silicone aluminum alloy has good castability properties, welding ability, durability, specific strength and corosion resistance [7]. Hardness of aluminum alloy increased with the addition of magnesium an increase in hardness is affected by the increment of magnesium addition toward aluminum alloy [8]. Mg is the basic element for the strength and hardness of the Al-Si-Mg alloy. The limit of the solubility of the addition of magnesium is around 0.7% Mg. Beyond this limit, no further reinforcement occurs. Al-Si-Mg with high magnesium content has light weight properties so it is needed in the industry with its low density and good wear resistance [2,7]. The mechanical characteristics of these alloys are influenced by the grain size, distribution and morphology of both alloys in the microstructure [3, 5].

Table-1. Aluminium alloy classification.

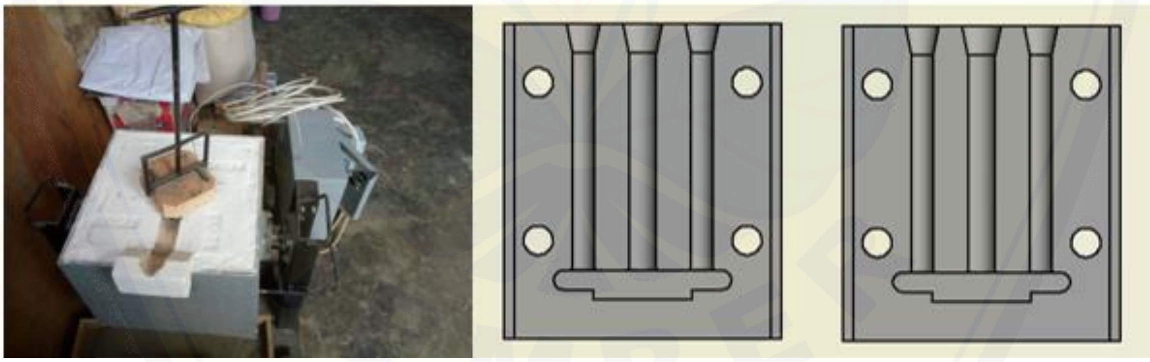
Alloy and Composition	Melting Point Temperature (°C)	Casting Temperature (°C)
Al 12Si	574	670-740
Al 9,5Si 0,5Mg	557	670-740
Al 7Si 0,3Mg	557	670-740
Al 12Si 0,8Cu 1,7Mg 2,5Ni	538	670-740
Al 9Si 3,5Cu 0,8Mg 0,8Ni	520	670-740

2.2 Casting

The casting process is one of the oldest methods in shaping material where it has been conducted since 6000 years ago. The principle of casting is very simple: melting the metal, pouring it into the mold, and then allowing it to cool and harden. However, there are many factors and variables that must be considered in order to achieve a good casting operation [9]. When conducting the casting, we must perform processes such as: melting of metals, molding, preparation, pouring of molten metal into molds, disassembly and cleaning of molds. As a molding material, it could be special steels or alloy cast irons. Materials for castings are generally non-ferrous alloys which have low melting points such as aluminum alloys, magnesium alloys or copper alloys [7, 10].

2.3 Experimental Method

Materials manufacturing for research of the Al-Si-Mg + Sr alloy is carried out by the gravity casting method. The process is firstly done by determining the weight of aluminum, magnesium and strontium based on the independent variables, namely Sr 0.02%, 0.04%, 0.06%, 0.08% weight. It then continues with cutting the material and mounting using resin. This is then continued with sanding with a pulp with a smoothness of 150, 320, 500, 800, 1000 and 1500. Polishing is then done using velvet and alumina cloth mixed with water. Then the etching process is carried out, where the etching process of the Al-Si-Mg material is according to ASTM E407-07. Etching is done using a mixture of 1 ml HF and 200ml of water. The duration of etching is 3 seconds where it is then dried with a heat gun. The microstructure of the Al-Si-Mg + Sr alloy is then placed under the microscope for the proper data extraction to be conducted.



(a) (b)

Figure-1. (a) Melting furnace (b) Mold specimen.

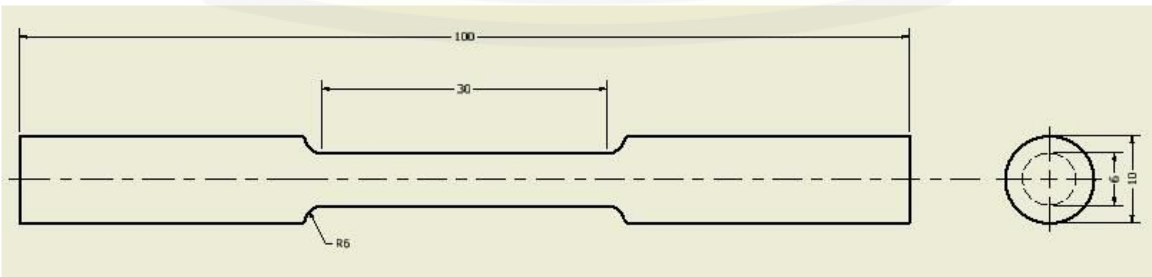
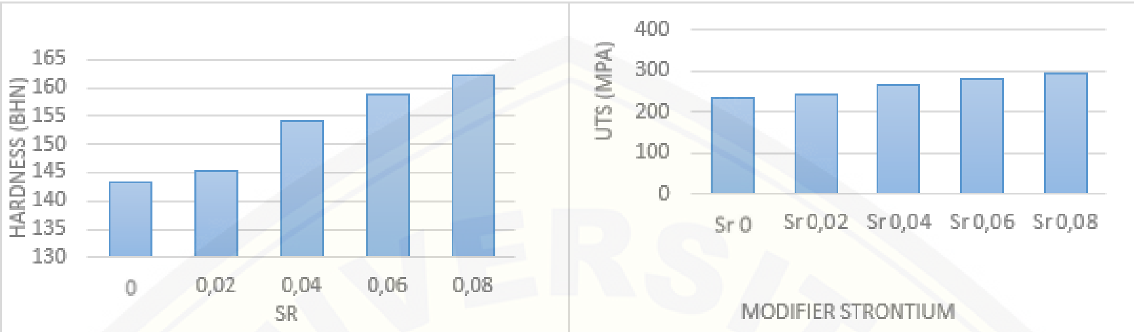


Figure-2. Tensile test specimen ASTM B557.

3. RESULT AND DISCUSSIONS

3.1 Hardness Test and Tensile Test

The hardness test of Al-Si-Mg alloy casting with the addition of strontium was carried out at 3 test points. This tensile test aims to determine or examine the tensile strength value of the Al-Si-Mg alloy before and after the addition of the strontium modifier. The tensile strength is to determine the maximum stress that could be handled by the material before it fractures where it is then analyzed for its material properties.



(a) (b)

Figure-3. (a) Hardness value of Al-Si-Mg alloys with the addition of strontium modifiers,(b) Value of the tensile strength of Al-Si-Mg alloys with the addition of strontium modifiers.

The highest value of hardness was 162.33 BHN with the addition of 0.08% strontium while the lowest hardness value was 143.44 BHN without the addition of strontium. The addition of 0.02% strontium in the Al-Si-Mg mixture caused a less significant structural change so that it obtained a hardness value that was almost the same as the Al-Si-Mg alloy without modifier. A significant change in the structure of the eutectic silicon occurs at the addition of 0.08% strontium to obtain the highest hardness value. This is from the eutectic structure of the silicon, which initially takes a rough acicular shape and is now a finer shape [4].

In Figure-3, it can be seen that the addition of strontium content in the Al-Si-Mg mixture can increase the tensile strength of the material. In general, the increase in the tensile strength of the Al-Si-Mg alloy with the addition of strontium reached 27.03% with the addition of 0.08% strontium content. The highest tensile strength value is in the addition of 0.08% strontium with a tensile strength of 293.758 MPa, while the tensile strength without the addition of strontium has the smallest tensile strength with a tensile strength of 231,248 MPa.

Before the application of strontium modifier, the eutectic silicon in the Al-Si-Mg alloy is still in an acicular form which its eutectic condition had a greater internal stress concentration, therefore the Al-Si-Mg alloy is weaker and more brittle. When the strontium modifier was added, the eutectic silicon form began to change to a more fibrous, finer form [6]. Alloys with the addition of larger amounts of modifiers, namely 0.04%, 0.06% and 0.08% strontium, their eutectic silicon structures become smoother and more evenly distributed. The fine eutectic silicon structure is what makes the tensile strength increase [4].

3.2 Micro Structure Analysis

Microstructure analysis is carried out to see the changes in the microstructure that occur due to the addition of the strontium modifier in the alloy. The analysis was carried out using a microscope with a magnification of 800X. Data from the microstructure test results can be seen in Figure-4. There are 5variations for this microstructure test, namely variations of 0% Sr, 0.02%, 0.04%, 0.06% and 0.08% Sr.

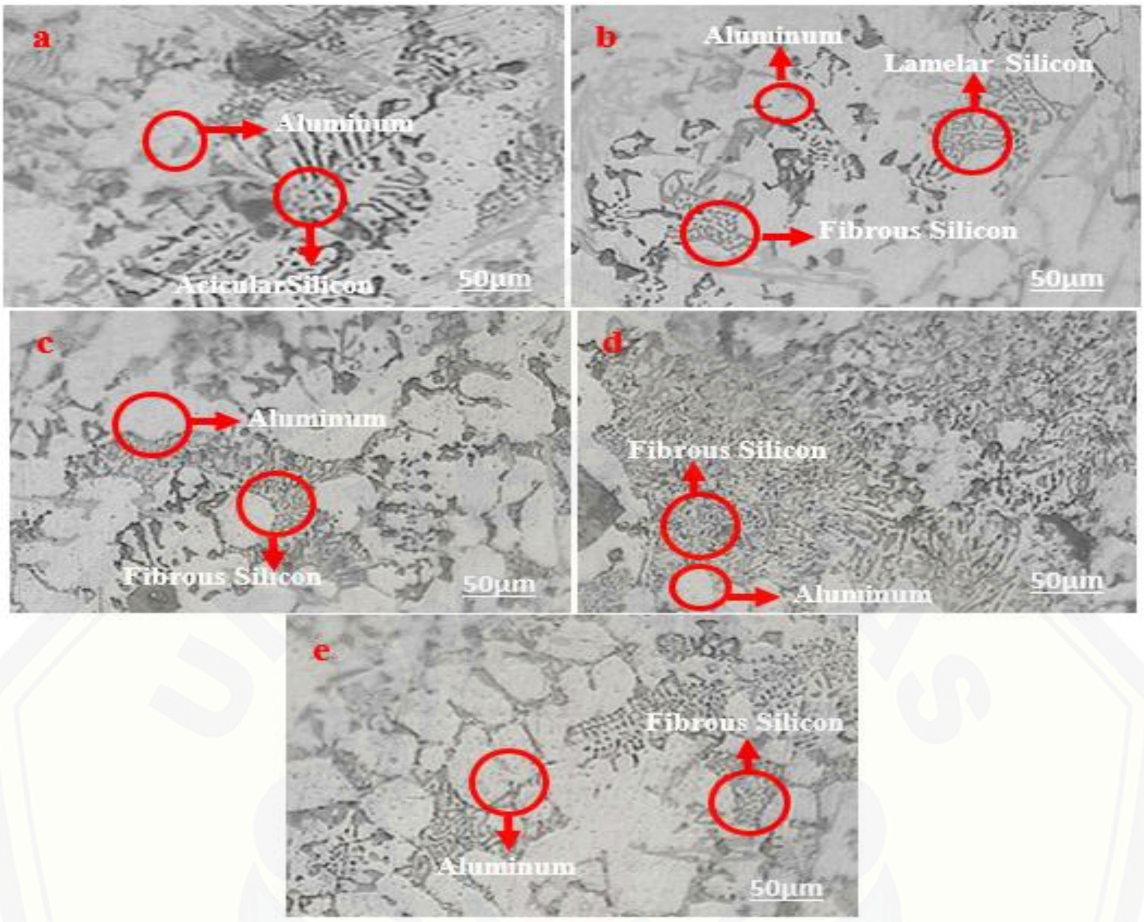


Figure-4. Microstructure of Al-Si-Mg alloy (a) without Sr modifier, (b) 0.02% Sr, (c) 0.04% Sr (d) 0.06% Sr (e) 0.08% Sr.

The results of the microstructure test above show that there is an effect of the addition of strontium on the microstructure of the Al-Si-Mg alloy. The addition of strontium in general is able to change the shape of the eutectic silicon particles from acicular particles into smoother shapes. [4]. This change can be seen in the 0% strontium sample with the addition of 0.02, 0.04, 0.06 and 0.08 strontium in the microscopic image results above. Before the addition of strontium or without the modifier, it can be seen that the microstructure of silicon has an acicular shape. Whereas after the addition of strontium in the alloy, the microstructure of silicon has a smoother shape. Significant microstructure differences occurred in alloys without modifier compared to alloys with the addition of 0.08% strontium.

4. CONCLUSIONS

From this research it could be concluded:

a) The addition of strontium modifier in the Al-Si-Mg alloy affects the hardness value of the Al-Si-Mg alloy. The highest hardness is found for the addition of 0.08% strontium with a hardness value of 162.33 BHN and a tensile strength value of 293.758 MPa.
b) From the results of the microstructure analysis, it was found that the shape of the eutectic silicon particles changed along with the addition of the strontium modifier. With the addition of strontium, the eutectic silicon with acicular microstructure became fibrous in the Al-Si-Mg alloy.

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