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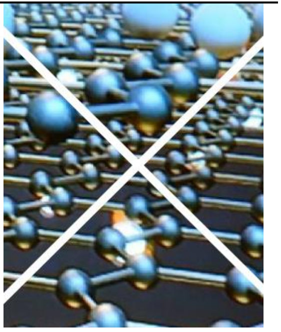

EFFECT OF SECONDARY AGING of EN AC 43200 ALUMINUM ALLOY to MECHANICAL PROPERTIES

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Abstract

In this study EN-AC 43200 Aluminum alloy was subjected to secondary or interrupted aging following T6 heat treatment. The 43200 alloy is used widely in the automotive industry for lowering the weightsof vehicles by substituting with ferrous alloys. This study covers the substitution of an automotive company’s part. 43200 Al alloy was melted under Argon atmosphere with an induction furnace, and cast into graphite molds. The samples were homogenized at 500 ^{o}C for 96 hours. Solutionizing treatment is also done at 500 ^{o}C for 14 hours, following water quenching; T6 treatment was done at 250 ^{o}C for 2 hours ended with a water quench. Secondary aging trials were done at 100, 150 and 200 ^{o}C for 2, 4, 6 and 8 hours for each temperature range respectively. Tensile tests and micro-hardness tests were applied for cast, T6 condition, and secondary aged samples. The samples were polished and observed for microstructure under the optical microscope. The maximum strength value of 370 MPa, and hardness 113 Hv was obtained from samples aged secondarily at 150 ^{o}C for 6 hours.

Keywords: Aluminum alloys, Optical microscopy, Tensile Strength, Hardness, Aging

1. Introduction

Today, substitution of aluminum alloys with high-density alloys in engineering applications is major design concerns of automotive manufacturers due to high fuel cost[1]. Aluminum and magnesium alloys are the first materials for reducing the weight of automobiles, especially the battery-operated cars [2] main structural parts need to have high specific strength.

Among these age-hardened aluminum alloys are the main candidates for reducing the vehicles' weight just as in aerospace vehicles [3]. However, the final cost of the structural element is another point to take care of because of huge mass production rates [4]. The 2XXX and 7XXX series age hardenable alloys more expensive than the EN AC 43200 Aluminum alloy. Therefore the EN AC 43200 alloy said to be compatible with 2XXX or 7XXX series aluminum alloys for its relatively high mechanical strength respect to its cost [5]. The studies about lowering the weight of vehicles go back to the '80s [6, 7]. There are some studies for reducing the weight of military or logistics vehicles by substitution of iron-based alloys with aluminum-based alloys were realized [8]. There are numerous studies about the secondary aging procedure for aluminum alloys. One of the studies was about AlSi10Mg alloy`s wear resistance [9], the overview of aging heat treatment of AlSi10Mg alloy was held by Vatansever et.al [10]. There are some studies about the effects of secondary aging and interrupted aging to aluminum alloys indicating that the secondary aging heat treatment is increased the mechanical properties [11-15]. The study aims to achieve superior properties from a cheaper aluminum alloy to substitute and compete with iron based alloys as well as 2XXX, and 7XXX series aluminum alloys by secondary aging heat treatment following a T6 treatment. This study was a demand from an automotive manufacturer for reducing vehicle weight by substituting cast iron component with an aluminum alloy.

2. Materials and Methods

EN-AC 43200, AlSi10Mg alloy locally obtained in 7 kg ingots. The ingots cut into small pieces approximately 10-15 mm in cubic forms, then melted in custom made induction furnace under an argon atmosphere, and cast into graphite molds to obtain cylindrical ingots in 10mm diameter. All cylindrical samples were homogenized at 500 ^{o}C for 96 hours, and cooled in the furnace to overcome the unfavorable effects of fast cooling in a graphite mold. Solutionizing heat treatment also was done at 500 ^{o}C for 14 hours and ended with water quenching. Aging heat treatment was done at 250 ^{o}C for 2 hours the samples were quenched in water at room temperature. Secondary heat treatment procedures were selected as at 100, 150 and 200 ^{o}C for 2, 4, 6 and 8 hours for each temperature range respectively. For every sequence of heat treatment, tensile tests and micrograph samples were prepared. Micro-hardness tests also were done from micrograph samples. Tensile tests were done with a Shimadzu AG-IS 250 universal testing instrument with 5 mm/min cross head speed. The samples were ground and polished with a Struers polishing instrument, the micrographs were taken with an Olympus PMG-3 microscope by Kameram software after etching with Keller etchant. The microhardness tests were done with Future Tech FV-800 hardness tester under 300g load for 10 seconds.

3. Results and Discussion

Tensile testing results of samples are given in Fig 1. As seen from the figure, tensile strength of the cast sample was found 218MPa, by the T6 heat treatment the strength was obtained as 280MPa. The secondary aging heat treatment at 100, 150 and 200 ^{o}C for 2, 4, 6 and 8 hours gives us different results. If tensile testing results inspected, the more stable condition can be said that around 150 ^{o}C, at the other temperatures the results are variable. By T6 heat treatment the increase in strength was found to be about 30 %, by adding a secondary heat treatment about 30% over T6, and about 70% over cast condition can be obtained. However the maximum strength obtained at 200 ^{o}C for 2hrs, but for the stability and lower temperature concerns, it would be desired to expose the samples at 150 ^{o}C for 6 hrs to get maximum strength value of 365 MPa.

The specific strength of T6 condition samples is around 85 kN•m/kg, if secondary aging treatment is done this specific strength reaches approximately 120 kN•m/kg value, whereas spheroidal cast iron's specific strength is around 77 kN•m/kg. From these results the heat-treated aluminum alloys can be strong candidates for substitution with iron-based alloys or cast iron. The wall thickness can be reduced, and the lightweight structures can be manufactured by an about 60% decrease in weight respect to iron-based structures.

The hardness values also taken for each sample, the same tendency was observed for the tensile tests (Figure.2). The as-cast sample's hardness value was found as 77Hv, by T6 heat treatment the hardness value was found as 101 Hv. The maximum hardness value of 114 Hv was obtained from the secondarily aged samples of 150 ^{o}C for 6 hours.

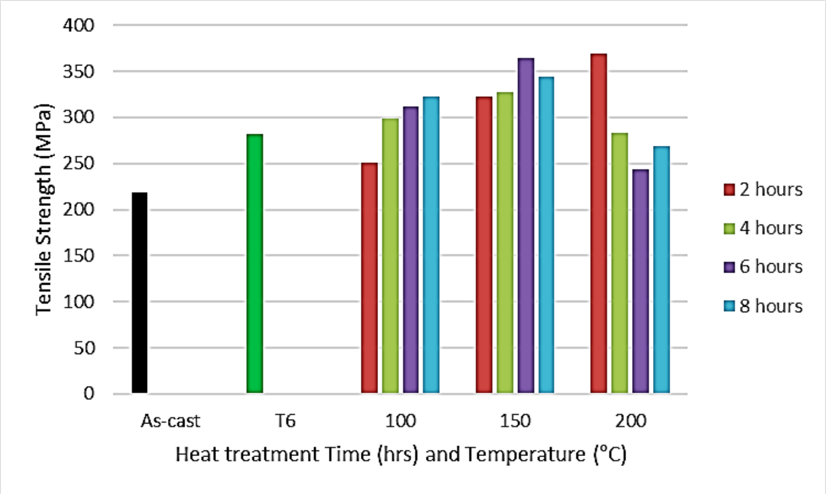

Figure 1. Tensile strength of samples at different conditions

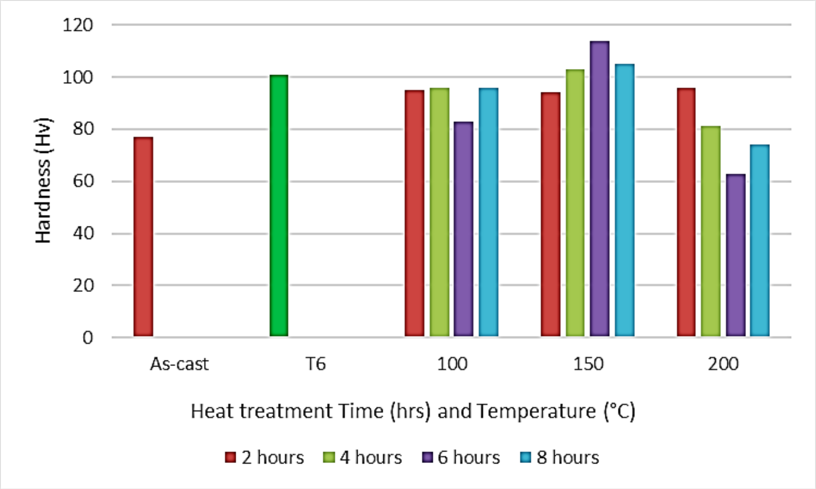

Figure 2. Hardness test results of the samples at different conditions

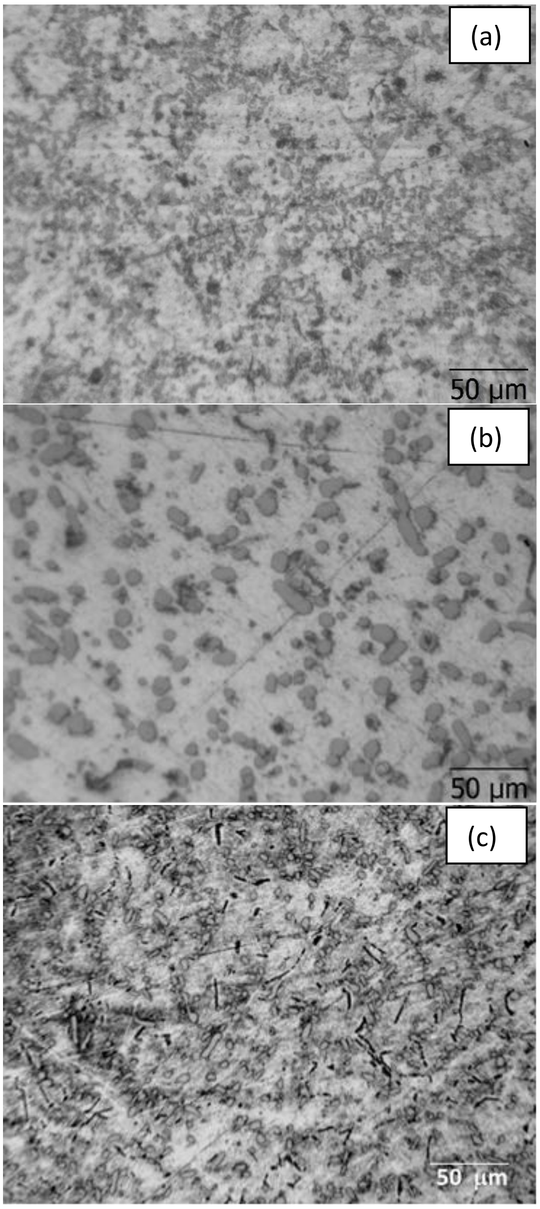

Figure 3. Microstructures of as-cast (a), T6 condition (b) 250 °C for 2 hours, secondarily aged (c) at 150 °C for 6 hours

The microstructure analysis revealed that the precipitates of MgSi are responsible for the increase in strength. The α-Al phase mostly seen phase in as-cast samples, by the homogenization heat treatment the α-Al phase islands are rounded. At the grain boundaries,the eutectic Al-Si structure was observed. With T6 and additional aging heat treatment Mg_2Si phase precipitated on α-Al phase. The microstructures of as-cast, T6 condition and secondarily aged samples were given in Figure.3.

The cast AlSi10Mg alloy has a microstructure consisting of primary α-Al dendrites and coarse eutectic mixture in the interdendritic area. Under T6 conditions, it is observed that the Si was getting more homogenous and spheroidal in the microstructure, whereas as-cast condition Si is getting thinner eutectic structure. There are different explanations for the effects of secondary phases in casting alloys on the aging process, depending on the alloy compositions involved. It is stated by that by the Mg-containing phases that may occur during solidification in the Al-Si-Mg system are Mg2Si and π-Fe phases [9]. In addition, it is stated that β-Fe and π-Fe ratios determine Mg and Fe content and solidification rate of the alloy as well as Mg content dissolved in the solid melt. A356 and 357 materials with low iron content (0.1-1.14%) in Al7SiMg alloy, higher magnesium, up to higher temperatures Mg containing π (FeMg3Si6Al8) phase increases the stability of the second, Mg2Si increased the temperature of magnesium β-AlFeSi5 phase [9]. Since the solid solubility of iron in aluminum is very low (0.05%), the iron is generally present in the second phase form as Al-Fe or Al-Fe-Si intermetallic. It is stated that there are three main phases in sub-eutectic and eutectic alloys containing Fe, Mn, and Mg and these are α-Al15 (FeMn) 3Si2 (α-Fe), β-Al5FeSi (β-Fe), πAl8FeMg3Si6 (π-Fe) [16]. In our study, the detailed study of precipitates was not held. All the assumptions based on previous studies.

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