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Energy Conservation during Heat treatment of A356 Aluminum Alloy

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Abstract

A standard heat treatment for Al-Si alloys consists of solutioning and artificial ageing. T4, T5 and T6 are the commonly used heat treatment methods for aluminum alloys. However, they need more than 4 hour for solutioning process and more than 6 hour for artificial ageing process. Unfortunately it requires long time to be carried out and therefore has significant financial implications. In the present study, solution treatment of A356 Al alloy was carried out in 1 hour and artificial ageing also carried out in 1 hour in three different heat treatment methods namely T4-Solution Treatment – TB Condition, T5-Precipitation (Ageing) – TE Condition and T6-Solution Treatment and Precipitation Hardening – TF Conditions. Finally obtaining almost same strength of materials compared to traditional heat treatment methods. The influence of the heat treatment on the hardness and tensile properties of the alloys along with that of the base alloy was investigated. It is observed that due to spherodization of silica particles T6 treated alloy showed a maximum hardness and strength compared to base alloy, T4 and T5 treated alloys.

Keywords: A356 Al alloy, Heat treatment, Hardness, Tensile strength

1. INTRODUCTION

Over the years, aluminum content in a vehicle part is increasing due to the needs to reduce weight as well as increase fuel efficiency. Most of the cast product in a vehicle part is mostly cast from A356 alloy due to its excellent characteristics over other type of alloy such as cast ability, high weight-to-strength ratio, good corrosion resistance and good weld-ability [1].The heat treatment of cast Aluminum alloys is done to increase their hardness and to change their physical, mechanical and metallurgical properties [2].Heat treatment was done to harness the full potential of cast A356 alloy and T6 heat treatment is the commonly used treatment for this alloy. Higher solution treatment temperature produces smaller and more globular Si particle before completing T6 heat treatment [4].

A standard heat treatment for Al-Si alloys consists of solutioning and artificial ageing. Solutioning process includes holding the alloy below the eutectic reaction temperature in order to dissolve the precipitations of Mg2Si and homogenize the chemical elements concentration on the cross-section of dendrites of α phase. In ageing, supersaturated alloy is soaked to separate strengthening phases from the super saturated solution [6]. The T6 heat treatment produces maximum strength (hardness) in aluminum alloys. Unfortunately it requires a relatively long time to be carried out and therefore has significant financial implications. However, they need more than 4 h for solution at 540°C, and more than 6 h for aging at 150°C, thus cause substantial energy consumption and low production efficiency. It is beneficial to study a method to reduce the holding time of heat treatment.

According to Rosso and Actis Grande, a solution heat treatment of 1 h at 540°C is sufficient to obtain a high level of mechanical properties in the T6 temper (hardness, yield strength, ultimate tensile strength and % elongation)[8].

2. EXPERIMENTAL DETAILS

Material

In the present study A356 alloy material having 6.14 % Si was used. The chemical composition of A356 alloy material is presented in Table 1. Castings are made from A356 alloy by melting the alloy in the induction furnace at 650°C and pouring it in to the sand mould. The cast samples are then cut and machined accordingly as per ASTM standards.

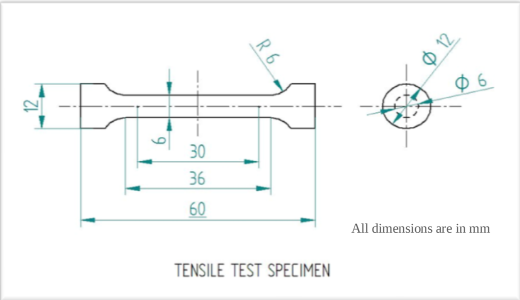

Fig.1: Tensile testing specimen

Table 1. Composition of A356 (Wt.%)

Element	Al	Si	Mg	Fe	Zn	Mn	Ti	Ni	Ca	Pb	P
Wt. (%)	93.2	6.14	0.425	0.180	0.063	0.013	0.009	0.006	0.005	0.002	0.002

Heat Treatment

The samples are heat treated and then subjected for mechanical testing. The different types of heat treatments are carried out separately on the machined samples.

1. T4-Solution Treatment – TB Condition (T4)- Castings are heated to a temperature just below the alloy melting point (dependent on chemical composition) and held at this temperature (dependent on alloy and cross-sectional thickness) a sufficient amount of time(1 hour) to allow the alloying elements to enter into solid solution.
2. T5-Precipitation (Ageing) – TE Condition (T5 or T51) Artificial aging treatment is carried out at temperatures above ambient, typically in the range of 150-200˚C (300-400˚F) in 1 hour.
3. T6-solution treatment and precipitation hardening-A356 alloy is subjected to solution heat treatment at 550°C for 1 hour followed by water quenching. Artificial ageing is performed by maintaining specimen at 170°C for 1 hour followed by air quenching.

Hardness

Brinell hardness measurements were carried out on A356 alloy for both heat treated and without heat treated conditions. The load of 500kgs was applied and an indenter of 10mm diameter steel ball was used. The average of all the three readings was taken as the hardness of base alloy, T4, T5 and T6 heat treated condition specimens.

Tensile test

The tensile tests were performing using a screw driven Instron tensile testing machine in air at room temperature. The cross-head speed was 1 mm/min. The strain was measured by using an extensometer attached to the sample and with a measuring length of 50 mm. The 0.2% proof stress was used as the yield stress of alloys. The specimens are prepared as per ASTM E8-M04 standard.

RESULTS AND DISCUSSION

Brinell hardness measurement carried out at a constant load of 500 kg in order to investigate the influence of heat treatment on hardness property of a material. Table 2.showsBrinell hardness number of A356 aluminum base alloy, T4, T5 and T6 heat treated conditions.

It is found that the hardness value increases in T6 heat treated condition compared with T4, T5 heat treated condition. This is due to the precipitation of alloying particles during T6 treatment.

Table 2.Brinell Hardness number

Specimen	Indentation Diameter	BHN
Base alloy	3.195	60.73
T4	3.52	49.73
T5	3.43	52.47
T6	2.69	86.36

The alloys were then subjected to tensile testing to investigate the yield strength, ultimate strength, young's modulus and elongation. The specimens are prepared as per ASTM E8-M04 standard. The results of tensile testing are tabulated below.

Table 3. Tensile Test results

Specimen	Young's Modulus (N/mm^2)	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	Elongation (%)
Base alloy	180	120	233	18.5
T4	93	80	131	3.33
T5	60	90	115	1.67
T6	208.3	160	238	16.2

It is observed that young's modulus (E) of T6 heat treated material is more compared with T4, T5 and Base alloy (without heat treated). The increase in strength of the T6 heat treated alloy is due to the spheroidization of the brittle silicon particles. It is also observed that base alloy is more ductile compared to heat treated alloys. Young's modulus (E) of T5 heat treated material is lower compared to that of T4, T6 and base alloy. The advantages of not using solution heat treatment include significant energy savings and less distortion of the components. However, spheroidization of the Silicon particles is not achieved in A356-T5 with deleterious effects on ductility and lower strength obtained in A356-T5. Artificial ageing enhances strength but reduces ductility of the primary Al particles. However, solution treatment under the T6 condition will lead to substantial grain growth, which in turn results in a decrease in ductility.

CONCLUSION

It has been observed that decreasing the time during T4, T5 and T6 will not affect much in the property of materials. A356 alloys were casted and then solution heat treated. Spheroidization of the brittle Silicon yields Young's modulus, Yield strength and ultimate strength during T6 heat treatment condition. Also, T5 condition is not suitable due to its deleterious effects on ductility and lower strength compared to that of base alloy, T4 and T6 heat treated condition.

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