EFFECT OF HEAT TRETMENT ON HARDNESS OF 6082-T6 ALMINIUM ALLOY

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Abstract: The present study investigates the effect of heat treatment parameters viz. temperature and time on the hardness of 6082-T6 aluminium alloy. Precipitation hardening heat treatment is performed on samples. Since natural aging takes too much time period to give desired properties; artificial aging heat treatment is done. Samples of 6082-T6 aluminium alloy are aged at various temperatures in the range 175^0C to 220^0C for 2 to 10 hours aging time. Also few samples are solution heat treated at 500^0C for 1 hour followed by water quenching prior to artificial aging. Hardness of samples is tasted and also their relation with aging time is assessed. The results show that the changes in grain size and grain structure during solution heat treatment and artificial aging process are responsible for change in hardness of alloy. Artificial aging without solution heat treatment causes coarsening of grain structure along with increase in brittle Mg_2Si phase. Particularly aging temperatures above 200^0C are more effective. Whereas samples solution heat treated prior to artificial aging causes distortion of grain structure. Both treatments causes reduction in hardness. Information contained herein can be useful in selection of precipitation hardening parameters viz. time and temperature to obtain required hardness.

Keywords: 6082-T6 alloy, Hardness, Artificial aging, Heat treatment.

1 INTRODUCTION

Aluminium is the most widely available metallic element in the solid portion of earth's crust. Unalloyed, pure aluminium is very soft and ductile. For structural and other applications alloying elements are added to obtain desired mechanical, physical and chemical properties, such as strength, toughness, corrosion resistance, etc. The 6xxx-series alloys use combination of magnesium and silicon which makes them heat-treatable. 6082 alloy shows highest strength in among all 6xxx series alloys. These alloys find their greatest strength, combined with good corrosion resistance, ease of formability and excellent ability to be anodized. These alloys are widely used in welding fabrication industry and in structural members. Magnesium and silicon are added either in balance amounts to form quasi-binary Al-Mg_2Si alloys (Mg: Si:: 1.73: 1), or with an excess of silicon above that needed to form equilibrium phase β (Mg2Si). This magnesium-silicide provides ability to become solution heat treated for improved strength.

Precipitation hardening occurs as a result of artificial ageing where the alloy is first heated to a temperature above the solvus line, however still below the eutectic temperature to avoid local melting of the alloy. This first initial step is known as solution heat treatment and is usually performed at temperatures close to 530 ^{0}C followed by quenching to room temperature. All alloying elements are then in solid solution and are said to be in a supersaturated solid solution (SSSS). [1]

The second step is artificial ageing; which involves heating the alloy to an intermediate temperature, usually 150-190^0C. However, a temperature range of 70-300 ^{0}C may theoretically be used and will result in precipitation of hardening precipitates [1]. During artificial ageing a series of meta-stable phases will precipitate with increasing holding time, until the equilibrium phase β (Mg_2Si) forms if the alloy is over-aged. the precipitation sequence may be written as:

$$\text{SSSS} \rightarrow \text{solute clusters} \rightarrow \text{GP-zones} \rightarrow \beta'' \rightarrow \beta' \rightarrow \beta\ (Mg_2Si)$$

Where,

SSSS is the Super Saturated Solid Solution, GP zones are generally considered spherical clusters with unknown structure. β" are semi-coherent fine needle-shaped $Mg_5Al_2Si_4$ zones with a monoclinic structure. β' are semi-coherent rod-shaped $Mg_{1.8}Si$ precipitates having a hexagonal crystal structure. β phase are usually Mg_2Si platelets having the FCC structure obtained if alloy is over-aged.[1]-[2]

In this paper effect of artificial aging with and without prior solution heat treatment at high temperature on hardness of alloy is studied.

2 EXPERIMENTAL

For all samples hardness was measured using Rockwell hardness test. Tests were carried out using Rockwell E Scale, 100kgf load and 1/8" ball Indenter on Rockwell hardness testing machine. A total of five readings were taken for every ageing time at the respective temperatures and average value was calculated. The tests were carried out in strength of materials laboratory of F.A.M.T. Ratnagiri.

2.1 Material Selection

In this research 6082-T6 alloy is used for test. Alloy composition of which is given in table 1.

Table 1 : Chemical composition of 6082 Al alloy

Alloying Element	Mg	Si	Mn	Cu	Cr	Zn	Ti	Fe	Al
%ge	0.60-1.20	0.70-1.30	0.40-1.00	0.10	0.25	0.20	0.10	0.50	Balance

The specimens were cut from sheet metal Al 6082-T6 by machine in dimensions (25*50*0.3) mm. The surface of all specimens is cleaned with acetone and then dried and saved in sealed container for next step. Material characteristics and general mechanical properties are given in table 2. [3]

Table 2 : General properties of 6082-T6 Al alloy

Material	Density (g cm-3)	Melting Point (liquidus) (^{0}C)	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation in 50 mm (%)
6082-T6	2.66	600	280	315	12

2.2 Heat Treatment Process

In order to study the effect of precipitation hardening and artificial aging on hardness, the samples were divided into two main groups for heat treatment by two different processes. Age hardening is the heat treatment performed on samples, to decrease hardness.

2.2.1 Experiment Number 01

This experiment is performed to study the effect of aging temperature and aging time on hardness of material. All samples were only artificially aged without prior solution heat treatment at high temperature. Five sub-groups each containing five samples were formed. Heating was carried out at 5 different temperatures viz. 175^{0}C, 185^{0}C, 195^{0}C, 205^{0}C, 220^{0}C. Samples of each sub-group are aged for different aging time periods viz. 2, 4, 6, 8, 10 Hrs.

2.2.2 Experiment Number 02

This experiment is carried out to study effect of precipitation hardening for small time period on hardness of material by Keeping independent variables same as in case of experiment number 01. All samples from second group are solution heat treated at 500^{0}C for 1 hour followed by water quenching and then artificially aged at various aging time and temperatures. Five sub-groups each containing five samples were formed from the initially heated samples. Heating was carried out at 5 different aging temperatures viz. 175^{0}C, 185^{0}C, 195^{0}C, 205^{0}C, 220^{0}C. Samples of each sub-group are aged for different aging time periods viz. 2, 4, 6, 8, 10Hrs. [4]

3 RESULT AND DISCUSSION

For aluminium alloy 6082-T6, the measured hardness value of untreated test specimen on Rockwell hardness test E scale is 68 HRE. This value is used to compare the sample that has undergone age hardening. Hardness results of both experiments are studied separately. All hardness values are measured in HRE numbers (Rockwell Hardness Number on E Scale).

3.1 Hardness results of experiment No. 01

Table 3 shows the changes in hardness of specimens on changing aging temperature and aging time.

Table 3 : Hardness results for specimens aged at various temperatures and time periods

Aging Time (Hrs)	Aging temperature				
	175^0C	**185^0C**	**195^0C**	**205^0C**	**220^0C**
2	69	69	68	67	64
4	70.2	70.5	70.5	66	63.5
6	70.5	71	71.5	64.5	62
8	70.8	71.8	72	64	61.5
10	69.5	69.8	71.3	62	60

It is observed that, without prior precipitation hardening; hardness of specimen goes on decreasing with increasing aging time. Figure 1 gives the graphical representation of effect of aging time on hardness of material for particular aging temperature.

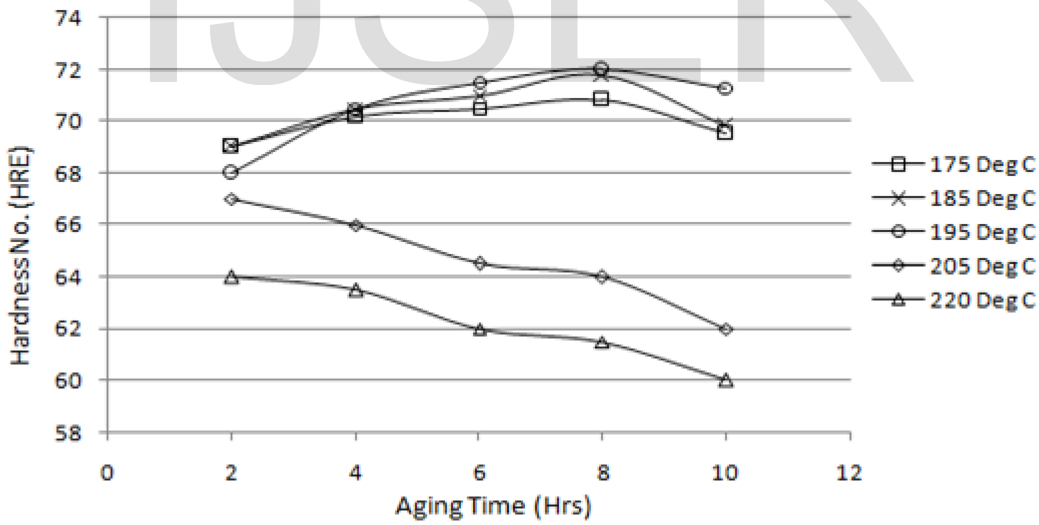

Fig 1 : Graph of aging time vs. hardness for 6082- T6 alloy aged at 175^0C, 185^0C, 195^0C, 205^0C, 220^0C

For aging temperatures below 200^0C there is no considerable increase or decrease in hardness values obtained at any aging time. For the samples aged above 200^0C, hardness decreases continuously with increase in aging time. Artificial aging without prior precipitation hardening causes over-aging of material and hence coarsening of grains. Also with increase in aging temperature, amount of Brittle β (Mg_2Si) phase increases. Hence at higher aging temperatures alloy shows rapid reduction in hardness with increase in aging time.

3.2 Hardness results of experiment No. 02

In this experiment solution heat treatment is done, prior to artificial aging. After heating at 500^{0}C with holding time of 1 hour and quenching in water at room temperature the hardness obtained is 66 HRE. Effect of variation in aging temperature and time, with prior solution heat treatment at 500^{0}C, on hardness of specimen is shown in Table 04. It can be observed that hardness went on decreasing with increasing aging time.

Table 4 : Hardness results for specimens solution heat treated at 500^{0}C for 1 hr and aged at various temperatures & time periods

Aging Time (Hrs)	**Aging temperature**				
	175^{0}C	**185^{0}C**	**195^{0}C**	**205^{0}C**	**220^{0}C**
2	66	66.5	67.2	67	67
4	65	65.5	66.5	66.5	65.5
6	64.5	63.5	66.2	65.2	65
8	63	62.5	65.8	64.8	64.2
10	62	61.5	65	64	63.5

Figure 02 gives the graphical representation of effect of aging time on hardness of material when it is heated previously. At lower aging time hardness remains unchanged irrespective of change in aging temperature. Although heating temperature is higher in this case failure in achieving increasing hardness is due to insufficient soaking time. Hardness number before heating is 68 HRE whereas after heating it becomes 66 HRE. It shows that there is no considerable effect of solution heat treatment on material.

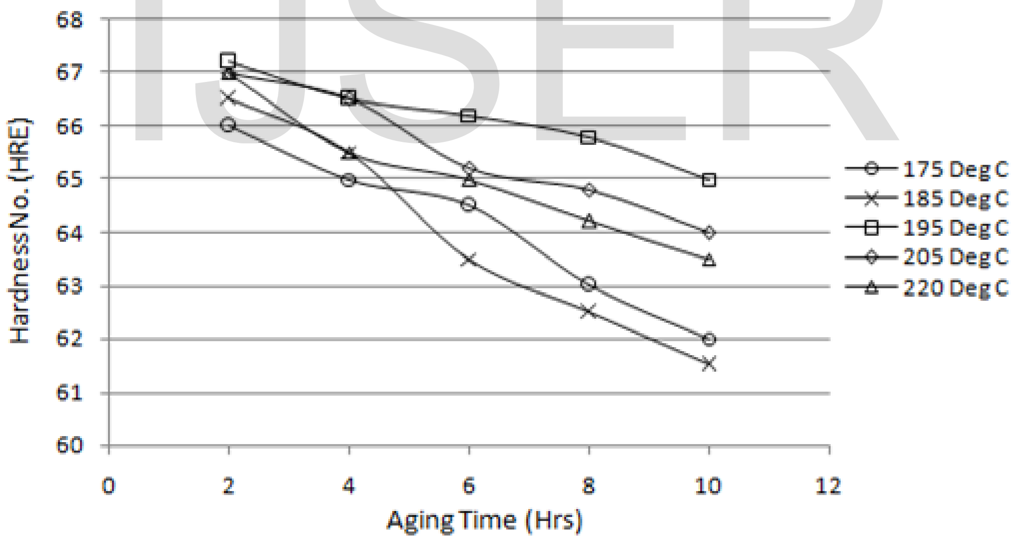

Fig 2 : Graph of aging time vs. hardness for 6082- T6 alloy solution heat treated at 500^{0}C for 1Hour and aged at 175^{0}C, 185^{0}C, 195^{0}C, 205^{0}C, 220^{0}C

It indicates that low soaking period is insufficient to change properties of material. However due to quenching established grain structure gets distorted. Further aging causes reduction in hardness since increase in aging time causes over-aging of specimen.

4 CONCLUSION

The result of the current study leads to the following conclusions:

- Variation in solution heat treatment temperature and time as well as aging temperature and time causes changes in grain structure and grain size and hence plays significant role in changing hardness values.
- Artificial aging without prior solution heat treatment increases percentage of brittle β phase along with coarsening of grains, both of which reduces hardness of alloy.
- Insufficient soaking time makes the effect of heating null hence; to obtain effect of precipitation hardening proper soaking time should be provided.

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