Research Article

Influence of Heat Treatment on Compressive Strength of Special Aluminum Alloys-AU5GT, AS7G06

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Abstract: Potentially sensitive materials have structural strength to tolerate loads be disposed to shrink dimension. The target of existing study is to associate the compressive strength of two material (AU5GT and AS7G06), which are utilized in diverse structural applications. At quite few heat treatment sequences, it's problematic to conclude the compression strength of subsequent aluminum mixtures. Specimens are heat treated first as per premeditated progressions, later compression testing is implemented. Compression test is piloted in accordance with ASTM E9-09 standard method on three samples with and bereft of heat treatment for separately sequences. Solution zing on trials is ended at perpetual period and temperature to achieve homogenization. Then, the aging treatment is conceded at diverse heats from 100 to 200 °C (different intervals) for a particular period of your time to perceive the influence of the rigidity of the precipitation and thus increase the resistance. Sample compressive strength is decided using Universal Testing machine for every heat treatment cycle. The heat-treated AS7G06 displayed insignificant distortion, but the heat-treated model revealed enlarged AU5GT aluminum composite strength. Since slush, because it's very difficult to emerge as a rise in temperature precipitation, results in the harder areas of whole grains. Unsurprisingly, hardness also showed a rise in proportion. Analyze the fracture surface employing a stereomicroscope and a scanning microscope (SEM) to seek out the last sort of brittle, soft or transient fracture (combination of brittleness and ductility).

Keywords: Compressive Strength, Heat treated non-heat treated, Fracture surfaces; scanning electron microscopy (SEM)

1. Introduction:

Aluminum fusion compounds are widely used in the automotive, power transmission, shipping setup advancement, space and defense engineering. The rapid development of aluminum composites in industrial uses is associated with great power / bulk proportions that advancing mechanical properties and product performance. Among the diverse fusion composites, aluminum fusion composites are very
widely held due to the highest level of fusion, good flow ability and relatively low melting point. It’s less mass and great power / bulk proportion are the key facts why steel parts are gradually being swapped by aluminum composites, specifically in the locomotive sector. The choice of forming composite often depends on the comparative capability of the composite to encounter unique or additional properties essential for a particular use. This presented study is focused on the compressive strength of two grades of Aluminum i.e. AS7G06 and AU5GT. The main components of aluminum are AS7GT, magnesium, titanium, AU5G06 silicon, steel, brass, magnesium and titanium. Table 1 summarizes the precise measurements of aluminum alloys, and the rest is aluminum.

**Table 1 Chemical composition (%) of AU5GT and AS7G06**

| Composition of AU5GT composite |  |
| Mn | Cu | Fe | Si |
| 0.090 | 4.30 | 0.120 | 0.130 |
| Zn | Mg | Ni | Ti |
| 0.090 | 0.280 | 0.0040 | 0.20 |

| Composition of AS7G06 composite |  |
| Mn | Cu | Fe | Si |
| 0.0040 | 0.0010 | 0.130 | 6.760 |
| Zn | Mg | Ni | Ti |
| 0.0010 | 0.560 | 0.0030 | 0.10 |

German metallurgist Alfred Wilm revealed aged precipitation or hardening of an aluminum composite more than 100 years ago, but this concept is not yet abundantly agreed and is being further tested all over the world. The aging heat, interval and definite formation of the composites do not have a certain effect on the engineering characteristics of these composites. For instance, modern analyses have shown that the stretch ability of some composites mitigate in the earliest time of aging and then strengthen, reaching values superior to molded composites [1]. The compression effect increases with the number of joints. Performing a T6 treatment on heat treated samples before pressure activation increases the sample size by a factor of 4. Yasim studied the effect of heat treatment on the strength and strength of (2024) aluminum alloys [2]. The effects of temperature, aging time, and temperature in solution were investigated, and an important relationship relates to the degree of difficulty and stability. Salehudin et al explain the correspondence between heat treatment and exposure to aluminum energy AA6061 and AA6063 [3]. Abubakar et al
studied the environmental properties of selected 6061 aluminum alloys (water and palm oil) to determine changes in mechanical properties such as tensile strength, hardness and impact strength [4]. Many authors also work on impact toughness and other mechanical properties of different aluminum alloys [5-8]. Speedy conserving of the composite at ambient temperature abstain the establishment of precipitates that can adversely affect mechanical characteristics and deterioration conflict [9]. The foremost constraint for a composite structure to retort to warmth dealing is that the compact dissolvability of single or additional composite origins decreases meaningfully with reducing temperature [10]. Aging is categorized by ordinary aging, specimens are retained in ambient condition, and synthetic aging is executed at elevated temperatures. Most things, such as rigidity and conduct ability are affected by aging as a function of interval and heat [11]. Patricia Marian Cavalkoet. Alabama. (2009) summarize the development of coarse-grained deterioration and equate with simple deterioration. The outcomes illustrate that the tendency of warmth treatment of inter-grained corrosion aluminum composite rest on the chilling ratio. While the aluminum composite is deliberately ventilated at high heats, the alloying rudiments precipitous from dense and dispersed solutions, directed on grin boundaries, small gaps, un-dissolved bits, dislocations and further deficiencies in the aluminum mesh. In order to accomplish ideal performance, it is necessary to decline the dissemination progression and preserve the alloying constituents in dense mixture. This is achieved by stopping the temperature of the solution [12]. Ankit Kumar K. Shriva Set. Alabama. (2016) appraised a chain of aluminum composite fine pattern and discussed the prominence on machine-driven characteristics. 7075-T6 aluminum composite has admirable elastic limit, relicense and defect resistance. It has been originate that 7075-T6 aluminum composites entail supplementary drive to promulgate crashes. Sufficient space required to study the microstructure of 7075-T6 aluminum composite [13]. The literature review above shows that it has a great influence on the mechanical properties of thermally treated aluminum. There are many factors that can be included in heat treatment cycle, but due to limited experimental facility only two parameters are selected as per ASM handbook guidelines [14]. Solutionizing and aging temperature are set at different levels in order to investigate the compressive strength of aluminum alloys. To find the effect of heat treatment on compressive strength, an experimental plan is developed at different temperatures. The heat treatment cycle is designed and conducted in two stages. First the hardening mechanism dissolves the hardening solution and homogenizes it with aluminum. This will effect in a distinct regularized stage. Secondly, the artificial aging mechanism is preceded to precipitate out the desired hard regions that may significantly increase hardness and compressive strength. The samples were kept at five different aging temperatures to understand the effect on compressive strength. Examine the broken surface of the test sample with SEM (scanning electron
microscopy) to see if there are localization, separation or compression errors at different temperatures during heat treatment.

2. Experimental setup:
Current section discusses the preparation of samples, heat treatment of specimen, experimental determination of compression strength and micro-hardness.

2.1. Specimen Preparation:
The present effort has been done to explore the compressive strength of special aluminum alloys AU5GT and AS7G06 with standard and non-standard geometries in heat treated and non-heat treated conditions. The material has purchased in square bar shape having 90 mm thickness and 250 mm length for each alloy. From the raw material 24 specimens has been prepared from both aluminum alloys, 12 specimens are prepared for compression testing according to ASTM E9-09 standard (diameter 13 mm, gauge length 25 mm) and 12 specimens of cubic shape (5 mm, 5 mm, 5 mm) of non-standard [15]. Electrical discharge machine (EDM) used for specimens cutting for compression testing.

2.2. Heat Treatment:
The prepared specimens both standard and non-standard have been heat treated at different condition. Heat treatment has been done in two phases. In the first phase all specimens of both alloys and both geometries has subjected to solution annealing at temperature of 300°C for interval of 60 minutes, dipped in warm hot water consuming hotness 60-70°C. Now the next segment all solution annealed specimens has been venerable at 100°C, 125°C, 150°C, 175°C and 200°C for 60 minutes and ventilated at ambient temperature. The heat treatment sequence displayed in the Figure 1 and investigational heat treatment design revealed in Table 2. Metallic materials consist of a microstructure of small crystals called "grains" or crystallites. The nature of the grains (i.e. grain size and composition) is one of the most effective factors that can determine the overall mechanical behavior of the metal. Heat treatment provides an efficient way to manipulate the properties of the metal by controlling the rate of diffusion and the rate of cooling within the microstructure. Heat treating is often used to alter the mechanical properties of a metallic alloy, manipulating properties such as the hardness, strength, toughness, ductility, and elasticity. There are two mechanisms that may change an alloy's properties during heat treatment: the formation of martensitic causes the crystals to deform intrinsically and the diffusion mechanism causes changes in the homogeneity of the alloy. The crystal structure consists of atoms that are grouped in a very specific arrangement, called a lattice. In most elements, this order will rearrange itself, depending on conditions like temperature and pressure. Many metals and non-metals exhibit a martensitic transformation when cooled quickly (with external media like oil, polymer, water etc.). When a metal is cooled very quickly, the insoluble atoms may not be able to migrate out of the solution in time. This is called “diffusion less transformation.” When the crystal matrix changes to its low
temperature arrangement, the atoms of the solute become trapped within the lattice. The trapped atoms prevent the crystal matrix from completely changing into its low temperature allotrope, creating shearing stresses within the lattice. When some alloys are cooled quickly, such as steel, the martensitic transformation hardens the metal, while in others, like aluminum, the alloy becomes softer. When in the soluble state, the process of diffusion causes the atoms of the dissolved element to spread out, attempting to form a homogenous distribution within the crystals of the base metal. If the alloy is cooled to an insoluble state, the atoms of the dissolved constituents (solutes) may migrate out of the solution. This type of diffusion, called precipitation, leads to nucleation, where the migrating atoms group together at the grain-boundaries. This forms a microstructure generally consisting of two or more distinct phases.[4] For instance, steel that has been heated above the austenizing temperature (red to orange-hot, or around 1,500 °F (820 °C) to 1,600 °F (870 °C) depending on carbon content), and then cooled slowly, forms a laminated structure composed of alternating layers of ferrite and cementite, becoming soft pearlite.[5] After heating the steel to the austenite phase and then quenching it in water, the microstructure will be in the martensitic phase. This is due to the fact that the steel will change from the austenite phase to the martensitic phase after quenching. Some pearlite or ferrite may be present if the quench did not rapidly cool off all the steel. Unlike iron-based alloys, most heat treatable alloys do not experience a ferrite transformation. In these alloys, the nucleation at the grain-boundaries often reinforces the structure of the crystal matrix. These metals harden by precipitation. Typically a slow process, depending on temperature, this is often referred to as "age hardening". Annealing consists of heating a metal to a specific temperature and then cooling at a rate that will produce a refined microstructure, either fully or partially separating the constituents. The rate of cooling is generally slow. Annealing is most often used to soften a metal for cold working, to improve machinability, or to enhance properties like electrical conductivity.

In ferrous alloys, annealing is usually accomplished by heating the metal beyond the upper critical temperature and then cooling very slowly, resulting in the formation of pearlite. In both pure metals and many alloys that cannot be heat treated, annealing is used to remove the hardness caused by cold working. The metal is heated to a temperature where recrystallization can occur, thereby repairing the defects caused by plastic deformation. In these metals, the rate of cooling will usually have little effect. Most non-ferrous alloys that are heat-treatable are also annealed to relieve the hardness of cold working. These may be slowly cooled to allow full precipitation of the constituents and produce refined microstructures.
Table 2 Investigational heat treatment design

<table>
<thead>
<tr>
<th>Solutionizing Temperature °C</th>
<th>Retention Interval (Minutes)</th>
<th>Aging Temperature °C</th>
<th>Retention Interval (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>60</td>
<td>100</td>
<td>60</td>
</tr>
<tr>
<td>300</td>
<td>60</td>
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<td>60</td>
</tr>
<tr>
<td>300</td>
<td>60</td>
<td>200</td>
<td>60</td>
</tr>
</tbody>
</table>

Heat treatment is carried out in accordance with ASTM-B918-01 (heat treatment standard for aluminum composites). In mechanical engineering department NEDUET Karachi muffle oven of material and metallurgical laboratory is used for heat treatment of aluminum composites. Strength of materials, also called mechanics of materials, deals with the behavior of solid objects subject to stresses and strains. The complete theory began with the consideration of the behavior of one and two dimensional members of structures, whose states of stress can be approximated as two dimensional, and was then generalized to three dimensions to develop a more complete theory of the elastic and plastic behavior of materials. An important founding pioneer in mechanics of materials was Stephen Timoshenko.
2.3. Compression Testing

Compression testing has been conducted on all specimens as per ASTM E9. Six samples have been tested of each aluminum alloy, five heat treated specimens at different aging temperatures and one non-heat treated specimens has been tested of each grade. Compression testing has been performed on universal testing machine (UTM) at room temperature and loading rate of 0.5KN/sec. Load- displacement graphs were attained and crucial compressive strength and percentage of strain values were calculated from Load- displacement graphs.

From Figure 2 stress-strain curves at different ageing temperatures it results in enhancement in compressive strength which increase the yield strength also. From Figure 3 it is concluded that as increasing ageing temperature the microstructure become fine and improved compression strength. Alloys are defined by a metallic bonding character. The alloy constituents are usually measured by mass percentage for practical applications, and in atomic fraction for basic science studies. Alloys are usually classified as substitution or interstitial alloys, depending on the atomic arrangement that forms the alloy. They can be further classified as homogeneous (consisting of a single phase), or heterogeneous (consisting of two or more phases) or intermetallic. An alloy is a mixture of chemical elements, which forms an impure substance (admixture) that retains the characteristics of a metal. An alloy is distinct from an impure metal in that, with an alloy, the

![Figure 2 Ultimate compressive strength of AU5GT](image)
added elements are well controlled to produce desirable properties, while impure metals such as wrought iron are less controlled, but are often considered useful.

![UCS & Yield Strength vs Ageing Temperature](image)

Figure 3 Maximum Compressive strength and yield strength at different ageing temperature

2.4. Microscopic Examination

All microscopy samples contained 2 ml HF and 3 ml HCl, 5 ml HNO₃ 190 ml water (ASTM E 407 [13]). Changes in the micro blot Iron balance were measured by heat treatment using fluorescent microscopy by exploiting given in Figure 4. An alloy is a combination of metals or metals combined with one or more other elements. For example, combining the metallic elements gold and copper produces red gold, gold and silver becomes white gold, and silver combined with copper produces sterling silver. Elemental iron, combined with non-metallic carbon or silicon, produces alloys called steel or silicon steel. In other cases, the combination of metals imparts synergistic properties to the constituent metal elements such as corrosion resistance or mechanical strength. Examples of alloys are steel, solder, brass, pewter, duralumin, bronze and amalgams. An alloy may be a solid solution of metal elements (a single phase, where all metallic grains (crystals) are of the same composition) or a mixture of metallic phases (two or more solutions, forming a microstructure of different crystals within the metal). Intermetallic compounds are alloys with a defined stoichiometry and crystal structure. Zintl phases are also
sometimes considered alloys depending on bond types (see Van Arkel–Ketelaar triangle for information on classifying bonding in binary compounds).

![Fracture surfaces at 150°C aging temperature for (a) AS7G06 (b) AU5GT](image)

**Figure 4** Fracture surfaces at 150°C aging temperature for (a) AS7G06 (b) AU5GT

Metallurgical Microscope (IMM 901, NEDUET) and scanning electron microscope (SEM) FEI Quanta-200 is used to perceive the rupture faces of shattered samples for the evaluation of failure modes.

### 3. Results and Discussion

Purpose of current study is to investigate the effect of heat treatment on compressive strength for two different aluminum alloys. As described earlier, compression testing is carried out to determine the compressive strength which ultimately tells about the compressive strength of the material. The subsequent sections describe the different results of the investigational studies. As discussed earlier, lots of published material is available that explains changes occurs in material with respect to temperature (environmental) while current study elucidates the effect of aging temperature on compressive strength. The results are very important for all alloys used in the experimental study in our design compositions. The comparison about other studies is relevant inadequate for the general composite mixtures. The resulting mixture forms a substance with properties that often differ from those of the pure metals, such as increased strength or hardness. Unlike other substances that may contain metallic bases but do not behave as metals, such as aluminium oxide (sapphire), beryllium aluminium silicate (emerald) or sodium chloride (salt), an alloy will retain all the properties of a metal in the resulting material, such as electrical conductivity, ductility, opaqueness, and luster. Alloys are used in a wide variety of applications,
from the steel alloys, used in everything from buildings to automobiles to surgical tools, to exotic titanium-alloys used in the aerospace industry, to beryllium-copper alloys for non-sparking tools. In some cases, a combination of metals may reduce the overall cost of the material while preserving important properties.

Figure 5 Compressive strength vs Aging temperature

Above Figure 3 gives the plot of compressive strength and yield strength with respect to aging temperature (°C). It can be seen clearly that as increasing ageing temperature compressive strength and yield strength is increased. Following Figure 5 gives the plot of compressive strength of both aluminum alloys. It can be seen that AS7G06 aluminum alloy shows gradually decrease the compressive strength. The severity of the heat rap is the same. However, compressive strength had shown a little increment just after the dip at 150°C because of the abnormal increase of Matrix hardness at 175°C and 200°C. For AU5GT aluminum alloy, apparent increase in compressive strength with respect to aging temperature can be observed. From Fig. 5, it can be seen that amongst two aluminum alloy, AU5GT gives us increase in compressive strength by applying the designed heat treatment cycle. The specific composition of an alloy system will usually have a great effect on the results of heat treating. If the percentage of each constituent is just right, the alloy will form a single, continuous microstructure upon cooling. Such a mixture is said to be eutectoid.
3.1. Microscopy

The figure 6 and 7 shows the microstructure of heated aluminum alloys (AU5GT and ASG706). This can be clearly seen in the photomicrograph in Figure 6 (a) at the temperature of 100 °C in AS7G06, the deposits of the aluminum matrix are few and some precipitation has started to accumulate along the grain boundaries. However, as the temperature rises, the micrograph shown becomes larger as shown in the figure. 6 (b) At 200 °C, large irregular intermetallic precipitates are located at the dendritic boundary of α-Al solid solution. Furthermore, the results of the belt tightening phase have also been found in some regions, but the sequence is random [16]. AU5GT is illustrated in the figure. 7 (a) and (b), the grain delimitation zone gradually thickens as the aging temperature increases from 100 °C to 200 °C. In addition, the distance between the components decreases as the temperature increases, packaging. Consequently, the complex silicon compounds are grouped on the grain boundaries, offering excellent impact resistance [17].

Figure 6(a,b) Micrograph of AS7G06 at 100°C, (b) micrograph of AS7G06 at 200°C

Figure 7(a,b) Micrograph of AU5GT at 100°C, (b) micrograph of AU5GT at 200°C
3.2. Fractography

All samples were dissolved at 300 °C for 5 different temperatures, with a difference of 100 °C when the difference was 25 °C or 200 °C. All images in Figure 8 at different temperatures, i.e. At 100, 150 and 200 °C it has cracks (soft) and cracks (soft) in mixed form. The opaque area is an old shoot, and the bright spots indicate soft, cracked areas. Completely it is described all in the Figure 8a,b at different temperatures, i.e. At 100, 150 and 200 °C ranges that the cracks (soft) and cracks (hard) in mixed morphologies. The opaque area is also an oldest shouted, and the bright spots indicate soft cracked areas for the alloy mixtures in our experimental study throughout the work.

![Figure 8 SEM photographs for AU5GT aluminum alloy for aging temperatures: (a) 100 (b) 150 (c) 200°C](image1)

The incidence of cracks also increases as the aging temperature increases due to rain from 100 to 200 °C. The AS7G06 alloy has a mixing failure condition, but the cutting area is larger than the AU5GT. Consequently, the compressive strength of the AS7G06 alloy is low (Fig. 9). In figure 9 (c), you can see the fractures (surroundings) which are almost retained.

![Figure 9 SEM photographs for AS7G06 aluminum alloy for aging temperatures: (a) 100 (b) 150 (c) 200°C](image2)
4. Conclusion
Experimental investigation is carried out to determine compressive strength amongst two aluminum alloys (AS7G06 and AU5GT). Heat treatment cycle is designed as per ASM hand-book guidelines, to enhance the compression strength. Compression test is conducted in accordance with ASTM E9-09, at different aging temperatures ranging from 100 to 200°C at the interval of 25°C. Heat treated samples generally shows higher compressive strength for AU5GT while decreased in AS7G06. Indeed, over time, precipitation increases, leading to more difficult areas. Perform stereoscopic and scanning electron microscopy (SEM) to understand surface properties. The crack surface shows the final crack transition (combination of sensitivity and ductility), but AU5GT has more plastic fracture surfaces than AS7G06. Therefore, AU5GT can provide higher overall compressive strength in designed heat treatment cycles. In the future, other mechanical tests may be included to fully describe the material. This allows you to choose the right material for different applications.

References


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Dedication
Not mentioned.

Conflicts of Interest
There are no conflicts to declare.

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