An Investigation Of The Effects Of Solution Heat Treatment On Mechanical Properties Of Aluminium 7075 Alloys

Mohan Kumar S, Govindaraju H K

Abstract: The present work describes the Effect of heat treatment on grain size of Al 7075 alloys. The melting furnace utilized for the casting of the aluminum is an electrical resistance heater with a mechanical stirrer coated with tungsten carbide. The ageing time was varied from 1 to 20 hours in the steps of 1 hour. Mechanical characterization was performed as per ASTM standards such as tensile strength hardness tests. Results of the study reveal that Ultimate tensile strength and hardness properties are enhanced as the ageing time increases. The technique of optical microscopy was used to examine sample specimen for microstructures, and the microstructure indicated uniform particle distribution in the matrix state. Experimental results shows that there is a fall in the micro-hardness number after 14 hours of ageing due to an increase in the size of fine π precipitates as well as precipitate coarsening. The ultimate tensile strength was found to be 417.29 MPa after 20 hours of ageing, which is approximately 83.44% higher than that observed for 1 hour ageing specimen. After heat treatment, the strengthening of Al7075 alloy depends on several factors such as precipitation hardening and grain size. Furthermore to examine the fracture a scanning electron microscopy was used to examine the tested samples.


1 INTRODUCTION

Due to their desirable properties such as lower density and sensitive strength, aluminum and its alloys have found widespread applications. They have been used in many areas such as food utensils, storage cans, heat retention foils, support structures, military and commercial vehicle structural components. The strength of aluminum and its alloys is due to its density property varying from ~2.7 g / cm3 and having the face centre cube shape, thereby preserving the stability until melting. The characteristics of aluminum alloys are highly dependent on microstructure behaviour, binding properties between the particles, different secondary techniques and heat treatment. The aluminum alloy categories are dependent on the use of alloying elements. 7xxx series consisting of Al-Zn-Mg-Cu fulfilled the use of aluminum alloys in structural applications. The components must be robust as they are subjected to various operating conditions. Ductility, strength, modulus and damage tolerance are some key aspects that must be considered for the use of material as structural applications. By following certain alloying processes, these properties can be established. Alloys for high-performance structural usages undergo age hardening process that is developed in the forming process, plates or extrusions. The sequential cycle has to be followed, i.e., for the design of alloys with high thickness. Casting, homogenizing, warm rolling, solution treatment, quenching and stress relief by stretching and ageing. [3]. The heat treatment mechanism for aluminum alloy begins at elevated temperatures with solution heat treatment to accommodate the elements in solid solution.

An example of 7075 alloy shows that it is heated to 4800C and the temperature is instantly decreased by keeping it in water called quenching. The alloy is very appropriate at this temperature to undergo different processes. Once this alloy is kept at a higher temperature than room temperature, the alloy strength increases with decreased ductility. Precipitate formation begins as it is kept at a super saturated level [4]. Alloy has higher strength, lower density, greater toughness and lighter weight along with corrosion resistant properties. Their application in automotive, aviation, structures and models has been prominent. [2]. Al and its alloys are used in the form of cast and wrought. This alloy is 3rd still used in its iron and steel application [3]. This material's ability to display the property of light weight and high strength compared to other Al alloys makes it a sought-after material for applications in airframes and high stress components [4]. The aluminum's reaction capacity depends on its ability to form an oxide layer to display the corrosion's positive effects. The decrease in resistance to corrosion depends on the percentage of the alloying element in it. Often there may be some solid precipitations or phases that interfere with the continuity of the developed oxide layer and significantly affect the matrix [5]. The method adopted to change the state of metal specimen's with respect to its structure of metallurgy, mechanical properties and variations in stress is considered as heat treatment. The alloys are classified into two subgroups; heat-treatable alloys and alloys that non-heat-treated. Aluminum alloy heat treatment falls under the category of heat treatable alloys that improves the materials hardness and strength. Alloys whose properties must be altered by cooling is classified as non-heat treatable alloys. Solutionizing, quenching and ageing are the main steps taken in the heat treatment process. Solution heat treatment is heating the alloy close to its eutectic temperature and keeping it for a specified long time to form a solid solution at that temperature. After solution heat treatment, quenching is followed to maintain the system in a super-saturated state [15]. The strength of the formed alloy also increases as the temperature increases. In some specimens that have the eutectic phase if the temperature rises above the required eutectic temperature than the results will affect this phase's
melting. Therefore, with consideration of this aspect, the choice of temperature should also be made.

2 EXPERIMENTAL PROCEDURE

Al7075 alloy is an incredibly interesting material that is primarily used for structural components that are extremely stressed. This material has a range of applications in the field of aerospace, automobile, marine and space. Table 1 demonstrates chemical composition of Al7075 alloy.

<table>
<thead>
<tr>
<th>Element</th>
<th>Cu</th>
<th>Cr</th>
<th>Mn</th>
<th>Mg</th>
<th>Si</th>
<th>Ti</th>
<th>Zn</th>
<th>Fe</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt. %</td>
<td>1.8</td>
<td>0.2</td>
<td>0.4</td>
<td>1.9</td>
<td>0.5</td>
<td>0.15</td>
<td>3.25</td>
<td>0.5</td>
<td>Balance</td>
</tr>
</tbody>
</table>

The melting furnace used for aluminum casting is an electrical resistance heater with a tungsten carbide-coated mechanical stirrer to ensure the stirrer’s better life. Aluminum melting furnace shown in figure 1.

Small pieces of size 10x10x10 mm were machined as cast alloy for Optical micrographic studies. Emery polishing was used to prepare sample samples using silicon carbide abrasive sheets, of course, medium and fine grit scale 300, 600, 800 & 1200. Using alumina as abrasive samples were cleaned dried and polished on a velvet cloth on a double-disk polishing machine using a diamond paste to get a mirror finish. In order to reveal the grain structure, further samples were etched using the keller's reagent (3%HCl+HNO3+HF)The Meiji microscope shown in figure 3. has been used to examine the highly polished surfaces and the Samsung camera has been used to capture microphotos.

2.1 Heat Treatment

Al7075 alloy specimens are machined to the desired size and subjected to the process of heat treatment (i.e. T6 condition). For two hours, the specimens were solutionised at 550 °C and quenched in water. Upon quenching, both natural and artificial ageing was adopted. Artificial ageing of water-quenched specimens was completed at 190°C for various ageing hours ranging from 1 to 20 hours in step of 1 hrs. Fig.2 shows furnace used for heat treatment used in the present study.

2.3 Optical Micrograph studies

2.4 Micro Hardness Test

Figure 4 shows Everone Vickers microhardness tester. Micro hardness tests were conducted at a load of 100 grams under a dwell time of 10 seconds on metallographically polished specimens.
2.5 Tensile Test
Tensile tests were conducted using TUE-C-400 universal testing machine as per ASTM E8 standards at M/s. Advanced Metallurgical Laboratory, Peenya, Bangalore, India. To quantify the ultimate tensile strength and ductility of each sample, an average of 3 results was considered. The strength of each material was taken as an average of three results. Figure 5 shows the tensile test specimen dimensions used in this present investigation.

3 RESULTS AND DISCUSSION

3.1 Microstructure Study
Al7075 alloy casting microstructure study shows improved fluidity, grain refinement, decreased dendrite arm size, different aluminum and eutectic boundary phases. Different artificial aging conditions microstructure study picture are shown in Figure 6. Enhanced mechanical, age-hardening and fracture properties showed in grain refining. The effects on the microstructure of heat treatment greatly improve the transgranular fracture ratio. It results in uniform strain within grains and improved grain boundaries bonding. The fracture toughness and ductility were enhanced because of increased resistance to fracture. Increased mechanical properties due to enhancing homogeneity of precipitated particles and Adequate crystallographic texture distribution.

3.2 Hardness Properties.
Heat treated Al 7075 alloy microhardness tends to increase as the ageing time increases up to 14 hours but then tends to gradually decrease. The specimen aged 1 hour showed 76 HV microhardness while 81 HV was shown after 2 hours of age shown in figure 7. Like this, the hardness was observed to increase up to 14 hours of ageing. After 14 hours of ageing, the microhardness was found to be 160 HV, which is nearly twice as recorded for a 1-hour ageing sample. Increasing aging period after 14 hours has shown a decrease in the microhardness values. The duration 1 to 12 hours is known as pre-aging period because cohesive Mg and Zn rich clusters together with GP zones are observed during this time nucleation. The precipitates tend to increase in size and coarsening of precipitates after 14 hours of ageing. As a result, the Al7075 alloy's microhardness begins to gradually decrease after 14 hours of ageing. Due to coarsening of precipitates, this phase is known as over-aging.
3.3 Tensile Properties
The heat treatment effect has been studied on the yield strength of Al7075 alloy. In the steps of 1 hour ageing time is varied from 1 to 20 hours and the yield strength obtained is shown in Fig. 8. The trend in yield strength was found to gradually increase up to 20 hours of ageing period. To start with, the yield strength was found to be 197.9 MPa and 211.9 MPa respectively after ageing time of 1 and 2 hours. The yield strength was observed to rise further to 217.17 MPa after 3 hours of ageing and continued to rise until 20 hours of ageing. The yield strength was observed 397.57 MPa after 20 hours of ageing, which is nearly double that observed for specimen aged 1 hour. After heat treatment, the strengthening of Al7075 alloy depends on many factors such as grain size and hardening of precipitation. Al7075 alloy's yield and ultimate tensile strength depend largely on the material's grain size. This form of strengthening is also known as reinforcement of Hall-Petch. Accordingly, the size of the grain is inversely proportional to the material yield strength.

4 CONCLUSION
It has been found from the investigation that Al 7075 alloy mechanical properties have been enhanced by increasing the ageing time after solution treatment. In 20 hours of ageing treatment, there was a considerable increase in ultimate tensile strength of 417.29 MPa which is almost double the times of 1 hour ageing heat treatment. As well as a decrease in hardness of alloy after 14 hours of ageing. All samples failed in ductile manner, revealing an increased ultimate strength with lowered structural defects as the ageing period increased. With few structural defects, tensile specimens are likely to achieve high peak strength values. It can be seen from the microstructure that the intermetallic precipitates are present and distributed evenly throughout the alloy material.

REFERENCES


