EFFECT OF SOLUTIONIZATION AND AGE HARDENING TIME & TEMPERATURE ON HARDNESS AND CORROSION BEHAVIOUR OF AA7075 ALLOY

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ABSTRACT

The desired properties of heat treatable aluminium alloys can be obtained by selecting appropriate solutionization and age hardening process. In this present investigation effect of solutionization and age hardening time & temperature on mechanical and corrosion behaviour of AA7075 alloy have been studied. 7075 aluminium alloy consists of Zn, Mg and Cu as major alloying elements, Si, Mg and Ti as minor alloying elements. This alloy has been solutionized at 470 °C for 2 hours and quenched in water. Specimen have been aged at 140 °C for 6 hours, over aged at 180 °C for 12 hours & stabilized and dual aged at 120 °C and 175 °C for 1 hour and cooled. Then Microstructure, hardness and corrosion behaviour of the above specimen are studied as per ASTM standards and compared. Dual aged specimens have shown better results than the other heat treatment conditions.

KEYWORDS: Solutionization, Age hardening, Hardness & Corrosion

1. INTRODUCTION

Every transportation, infrastructure, and utilities, which supply oil, gas, water, and electricity are vulnerable to corrosion. All of these important structures to human life and luxury can fail at any moment due to this phenomenon, sometimes this failure is catastrophic. The importance of corrosion management, monitoring, and prevention has become more and more important. It is necessary to review and evaluate new ways of managing corrosion and stop it. It is also crucial to review the corrosion behaviour of the materials so their service life, in several conditions, are often predicted. The major properties of aluminium are achieved by making its alloys and heat treatments. This leads to the formation of tiny hard precipitates which obstruct the motion of dislocations and improve its mechanical properties. Aluminium 7075 is majorly used for structural applications due to desired properties such as density, high strength, and toughness and corrosion resistance. In addition to that, Al 7075 is widely used in aerospace applications.

1.1 Heat Treating Aluminium Alloys

Heat treatment refers to heating and cooling of metals or alloys in order to get better mechanical properties. Alloys are classified into 2 categories such as heat treatable alloys and non-heat treatable alloys. Increase in strength in non-heat treatable alloys depends on cold work. In case of heat treatable alloys increase in strength is achieved by
heating and cooling. Heat treatment of aluminium alloys may be a three-steps: Solution heat treating involves placing the alloy at a high temperature and allow some period of time to achieve to homogeneous solid solution. Quenching refers to rapid cooling is applied to lower temperature results, precipitation of solute atoms in solution, the precipitated solute atoms located at grain boundaries. Quenching range of Al7075 alloy to be 400°C to 290°C. Precipitation of solute atoms either at room temperature or higher temperature refers to age hardening.

1.2 Aluminium Corrosion

The corrosion of metals is caused by an electrochemical process also known as oxidation-reduction reaction in which the released energy is converted to electricity. In this reaction, electrons are jump from one substance to another oxidizing the one that lost the electrons and reducing the one that received the electrons.

2. LITERATURE REVIEW

Itsaree Iewkitthayakorn et al.⁶ have studied the quality of anodic oxide film formed on the cast 7075 Al alloy substrate after solution heat treatment at temperatures of 450˚C about 4 hours was higher than that of 2h, 8h, 16h and without solution heat treatment. As a result of solution heat treatment at 450˚C for 4h, eutectic phase particles dissolved completely and low amounts of coarse black MgSi particles formed in the microstructure of the alloy substrates. The amounts of secondary phase particles were less dissolved at solution treated time of 2h and coarse black MgSi particles formed increasingly with prolong solution treated time of 8h and 16h. These resulted in defect and discontinuous oxide film formations. Therefore, the solution treatment at 450˚C for 4h was the optimum condition for the cast 7075 Al alloy substrates. Anawatiet al.¹ have studied the corrosion behaviour of AA7075-T651 alloy. They conducted immersion test in NaCl and HCl solutions at 35˚C based on ASTM B597 for 8, 16, 24 h. After that, characterization was carried through optical microscope and scanning electron microscope. Results recorded that, severe corrosion attack occurs after immersion test and variations in surface appearance and development of surface roughness and weight loss. The surface turns rough. The near surface layer disintegrates and detaches from the surface after immersion about 24 and 16 hours. Results showed that alloy was susceptible to intergranular corrosion.

Till the date lot of work has been carried out on solutionization and age hardening on mechanical and wear properties of AA 7075 alloys but not much work has been carried out on behaviour of alloy under corrosive atmosphere. In this present investigation an attempt has been made to study effect of heat treatment on corrosion resistance of alloy in acidic media.

3. EXPERIMENTAL PROCEDURE

3.1 Material Validation

As it is required to determine the conformity of the material’s construction, EDAX’s Energy Dispersive Spectroscopy (EDS) was taken in order to find out composition of the material as shown in figure 1.
Effect of Solutionization and Age Hardening Time & Temperature on Hardness and Corrosion Behaviour of Aa7075 Alloy

3.2 Heat Treatment

Muffle furnace was used to conduct the heat treatment process on all the samples. Initially all the sets of specimen (S1, S2, and S3) were solutionized at a temperature of 470 °C for time period of 2 hour and cooled to the room temperature using water quenching medium. First set of specimen (S1) were aged for a temperature of 140°C for a time period of 6 hours. 2nd set of specimen (S2) were over aged at 180°C for a time period of 12 hours. 3rd set of Specimen (S3) were dual aged at 120 °C and 175 °C for 1 hour and cooled.

3.3 Microstructural Analysis

The specimens were polished to get mirror reflection using suitable emery papers and polishing cloth. The specimens were then etched with modified Keller’s reagent and observed under Optical microscope at various magnifications.

3.4 Hardness Test

The specimens were prepared and the hardness test was carried using Rockwell hardness tester as per ASTM E18-19 standards as shown in figure 2. R_B scale using 1/16 inch diameter ball indenter.

3.5 Corrosion Test

The corrosion of metals is caused by an electrochemical process also known as oxidation-reduction reactions. Oxidizing the one that lost the electrons and reducing the one that received the electrons. Where oxidation occurs at anode and...
reduction occurs at cathode. As an electrochemical process corrosion needs the presence of a metal, oxygen, and an electrolyte. As per ASTM B597 standards, the untreated and heat treated rods were cut using wire EDM to prepare specimens for the corrosion tests as shown in figure 3.

![Figure 3: Corrosion Test Specimens](image)

3.5.1. Immersion Corrosion Test / Weight Loss Method

As per ASTM B597, specimens were cut to the dimensions 20x10x5 mm using EDM. After cutting polishing was done and washed to remove dirt. Then specimens were immersed in 10% NaCl solution for 48 hrs. Then specimens were weighed after washing and drying. Corrosion rate was determined by taking weights before and after testing. Same test conditions were considered for all heat treated specimen.

The same test was repeated using acid media. Now specimens were immersed in 12.5% of HCl solution for 24 hrs. Then specimens were weighed after washing and drying. Corrosion rate was determined by taking weights before and after testing.

Corrosion Patterns Studies

The corrosion patterns of all the samples were investigated using a scanning electron microscope (SEM). The samples were cut using a power cutter to dimensions of 10 X 10 X 5 mm for SEM analysis. The samples were polished to a scratch free condition using different grit emery and polishing cloth. The surfaces of samples were then examined for corrosion patterns using SEM.

4. RESULTS AND DISCUSSIONS

4.1 EDAX's Energy Dispersive Spectroscopy (EDS)

From the EDS, the composition of the material is in conformity with the specifications provided by the manufacturer. It is observed that the procured material is Al7075 alloy with the compositions as represented in table 1.

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight Percentage (wt. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium (Al)</td>
<td>88.79</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>4.72</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>2.68</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>1.56</td>
</tr>
</tbody>
</table>
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**Discussion:** The chemical compositions of the alloy taken as per specifications.

1. **Effect of Heat Treatment on Microstructure of AA7075 Alloy**

![Wrought AA7075 Alloy](image1)

![Aged AA7075 Alloy](image2)

![Over aged AA7075 Alloy](image3)

![Dual Aged AA7075 Alloy](image4)

**Discussion:** The microstructure (figure 4) consists of grains $\alpha$-Al (light) and $\alpha$-Al + Mg (Zn, Cu, Al)$_2$ eutectic phase at the grain boundaries (dark). The microstructure shows a high density of precipitates distributed homogeneously in the aluminium matrix, the precipitates essentially being non-coherent $\eta$ phase. Metallurgical microscopic structures show uniformly distributed precipitation inside the grains in aged condition (figure 5). Over aging increased Grain size (figure 6) and grains have become finer and finer after dual heat treatment (figure 7). This was the reason for improvement in the hardness of the material.

1.2. **Effect of Heat Treatment on Hardness of AA7075 Alloy**

<table>
<thead>
<tr>
<th>Samples</th>
<th>Rockwell hardness (HRB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As-received (S0)</td>
<td>84</td>
</tr>
<tr>
<td>Aged (S1)</td>
<td>98</td>
</tr>
<tr>
<td>Over aged (S2)</td>
<td>96</td>
</tr>
<tr>
<td>Dual aged (S3)</td>
<td>107</td>
</tr>
</tbody>
</table>

**Table 2: Hardness Test Results**
Discussion: It is observed that the dual aged sample (S3) had maximum Rockwell hardness number (HRB) of 107. This may be due to finer grain sizes (figure 8). Shows the Rockwell hardness (HRB) of aged, over aged, dual aged and pure Al7075 alloy specimens. In this case, aged, over aged and dual aged Al7075 specimens have more hardness values compared to pure Al7075 alloy due to creation of small and fine uniformly spread precipitate of MgZn in the aluminium matrix. During over aging, fine precipitate distribution is start transforming into coarser precipitate distribution. The reason for coarse precipitates is reduction in precipitate/matrix interfacial energy. This is the reason for decreasing hardness in over aging condition.

1.3. Effect of Heat Treatment on Corrosion Behaviour of AA7075 Alloy

Discussion: In order to determine the corrosion rate which is essential for the weight loss method the following equations is used.
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Corrosion rate (mm/year) = \( \frac{\text{Weight loss} \times K}{\rho \times A \times T} \) ................................ (1)

Where, \( \rho \) is alloy density in g/cm\(^3\), A is an exposed area in cm\(^2\), T is an exposure time in year and for corrosion rate in mm/year, \( K = 8.76 \times 10^4 \). The values calculated from the corrosion rate equation, it is observed that the overaged sample (S2) had higher corrosion rate of 2.783 mm/year as shown in (figure 9).

![Figure 9: Corrosion rate over different aging conditions immersed in HCl solution](image)

**Discussion:** The similar procedure of corrosion test was followed for three other samples but samples were immersed in 12.5 % HCl solution for 24 hours. Then samples were weighed after washing and drying and the corrosion rate was determined. Using equation (1), the values of corrosion rates were determined. It was observed that overaged sample (S2) had higher corrosion rate of 7.422 mm/year as shown in (figure 10).

![Figure 10: Effect of Corrosion Rate over different Aging Conditions Immersed in HCl Solution](image)

The differences in corrosion resistance of the alloys can be interpreted in terms of the size, distribution and composition of aging precipitates. Diffusion of Cu atoms from the matrix to the undissolved aging precipitates, especially for the grain boundary precipitates, occurs during aging. The increase of Cu content can result in the weak electrochemical active of MgZn2 phases. Therefore, compared over aged alloy, the corrosion resistance of the aged and dual alloy is better.

1.4. Effect of Heat Treatment on Corrosion Patterns of AA7075 alloy

![Images of corrosion patterns](image)
Impact Factor (JCC): 6.3393

NAAS Rating: 2.79

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Discussion: From (figure 11) and (figure 12), it is observed that specimen undergoes pitting corrosion. Pitting corrosion occurs due to damage of thin oxide film of Al7075 alloy. Chloride content present in NaCl and HCl solutions are damaging the oxide film results pitting. Precipitates present in the aluminium alloys have either higher potential or lower potential compared to solid solution phase. Severe corrosion occurs at outer layer of the specimen and it was detached from specimen surface leads to rough surface layer. This rough surface layer is covered by aluminium oxides and chloride complexes.
CONCLUSIONS

- AA7075 alloy has been solutionized and age hardened successfully.
- Dual aged specimen has shown maximum hardness compared to aged, overaged and wrought alloy. Dual aged specimen has shown 27% increase in hardness compared to wrought alloy.
- Over aged specimen has shown 14% increase in hardness compared to wrought alloy. Over aged specimen has shown 10% decrease in hardness compared to dual aged specimen.
- Microstructure of wrought alloy consists of α-Al and eutectic grains. Precipitation of non-coherent η phase is observed in heat treatment specimen. Fine grain structure is observed in dual aged specimen than any other condition. Corrosion resistance of AA7075 alloy varied with heat treatment conditions.
- Dual aged specimen has executed maximum corrosion resistance than wrought, aged and over aged specimens based on corrosion rate (mm/year). Corrosion rate of dual aged specimens is less compared to aged and over aged specimens.

ACKNOWLEDGEMENTS

I place on record, my sincere gratitude to Dr B N Sarada, Professor, and Department of Mechanical Engineering. I am extremely grateful and indebted for her, expert, sincere, valuable guidance and encouragement extended to me. I take this opportunity to record my sincere thanks to all the faculty members and non-teaching staffs for their help and encouragement. I also thank my Parents for their unceasing encouragement and support.

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