Influence of heat treatment on microstructure and corrosion behavior of 7xxx Al alloys

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Abstract: The influence of heat treatment parameters on mechanical characteristic of hardness and corrosion of aluminum alloys were studied. The 7xxx series aluminium alloy in rolled state was heat treated in the following conditions: solution treatment at 475±5o C for 60 minutes, quenched in water 40-60oC and artificial aging at 120, 150, 180, 210oC at different time of aging (60, respectively 300, 540, 720 minutes). The research consisted in intercrystalline corrosion and hardness tests in correlation with microstructure analysis of heat treated Al-Zn-Mg-Cu samples alloy, in order to obtain the best corrosion resistance and high mechanical characteristics. We observed that the hardness modifications and the variation of electrode potential are in correlation with structural modification which have place during aging. Thus, when temperature and the duration of aging increases, we achieves the maximum hardness (fine precipitates occurred), and when the hardness decrease, this phenomenon is resulted of appearance of coarse precipitates. The polarization curves show two zones: one which characterize an active process, in which corrosion current intensity increases over a small range of potential and second one , the passivation zone, which are characterized of a small change in current intensity within a high potential.

Key-Words: 7xxx aluminum alloys**,** Artificial ageing, Microstructure analysis, General corrosion

1 Introduction

The wide range use of aluminum and aluminum alloys in the transportation industry (aircraft, automotive industry, etc.) is based on superior mechanical characteristics of these alloys, low specific weight and corrosion resistance. Superior mechanical characteristics and optimal chemical characteristics of aluminum alloys are obtained due to the possible application of structural hardening treatments and compositional modifications The 7xxx series alloys are very strong heat treatable alloys and they can be strengthened through heat treatment (precipitation hardening) based on the combination of zinc (mostly between 4–6 wt %) and magnesium (range 1–3 wt %) [1,2]. The high strength Al-Zn-Mg-(Cu, Zr) system or 7xxx series alloys is a highly complex one and are greatly determined by the main phases in the alloys, i.e. Guiner-Preston zones, η′, η, T, S, Mg_2Si and Fe rich intermetallic phases [3-6].
In commercial 7xxx alloys, only η (MgZn2 ; (Al, Zn)2Mg), T (Mg3Zn3Al2 ; Al6Mg11Zn11) and S (Al2CuMg) phases could appear in his structure [5-8].
Unfortunately the additions of Zn and Mg decrease the corrosion resistance. The existence of micro oxide film defects, inhomogeneity, potential differences between intermetallic particles and aluminum matrix and galvanic couples conduct to localized chemical attack of aluminum alloys. The susceptibility of Al-Zn-Mg-(Cu) alloy to intergranular corrosion increase also when the alloy is exposed to solutions containing chloride ions.

2 Problem Formulation

The research consisted in intercrystalline corrosion and hardness tests in correlation with microstructure analysis of heat treated Al-Zn-Mg-Cu samples alloy, in order to obtain the best corrosion resistance and high mechanical characteristics.

2.1. Materials and Experimental Procedure

The material selected for investigations in this research was rolled 7xxx series aluminium alloys; the chemical composition of investigated alloy was determined according to ASTM standard methods. The Al-Zn-Mg-Cu samples was heat treated in the following conditions: solution treated at 475±5^o C for 60 minutes, quenched in warm water (40-60^{o}C) and then artificial ageing at

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different temperatures (120, 150, 180, 210°C) and different times (60, respectively 300, 540, 720 minutes). Solution treatment was made into laboratory room furnace and artificial ageing was made into furnace ITM 50 with automatically adjustment of temperatures. After heat treatment were performed mechanical tests to determine Brinell hardness. For the hardness tests we used a Hardness Tester with 2.5 mm diameter ball indenter and load 62.5 Kgf.

The corrosion was made in solution of 53g NaCl + 1000 ml distilled water and boiled in these solutions for 24 hours. After intergranular corrosion test, samples were prepared for microstructural analyzing in the following conditions: were grinded on metallographic paper up to 600 grit, polished with slurry of Al_2O_3 (1 µm granulation) and then etching with Villela's Reagent. (45 ml Glycerol, 15 ml Nitric acid and 30 ml Hydrochloric acid) according with specific standardization [9, 10]. To investigate the general corrosion resistance was used an electrochemical method: the electrochemical corrosion was made in the same type of solution like previous one (53g NaCl + 1000 ml distilled water), using a potentiostatic device type PAR (Princeton, Applied, Research) model 173. For the electrochemical corrosion tests we have linked the cell work to the potențiostatic device and we measured the stationary potential and the current density after a stabilization time of 2-3 minutes.

The device for electrochemical corrosion consisted between three electrode systems: the working electrode, which are the aluminum alloy sample, the auxiliary electrode (or counter electrode) and saturated calomel electrode as reference electrode. The working electrode was a cylinder of Al-Zn-Mg-Cu alloy with following dimensions: 10 mm in diameter and 20 mm in length. The working electrode area was 1 cm^2 (the remaining surface of the work-piece being coated with a resin). And the auxiliary electrode was platinum plate, placed in a separate compartment and protected by glass from the rest of the cell to prevent contamination of electrolyte by electrolysis products.

3 Problem Solution

The chemical composition of the Al-Zn-Mg-Cu alloy used in the present study is presented in Table 1.

Table 1

Ele-ment	Zn	Mg	Cu	Fe	Si	Ti	Al
(wt%)	5	1.5	1.24	0.29	0.03	0.02	Balance

The dependence of hardness on different condition of aging (temperature and times) is shown in Fig 1.

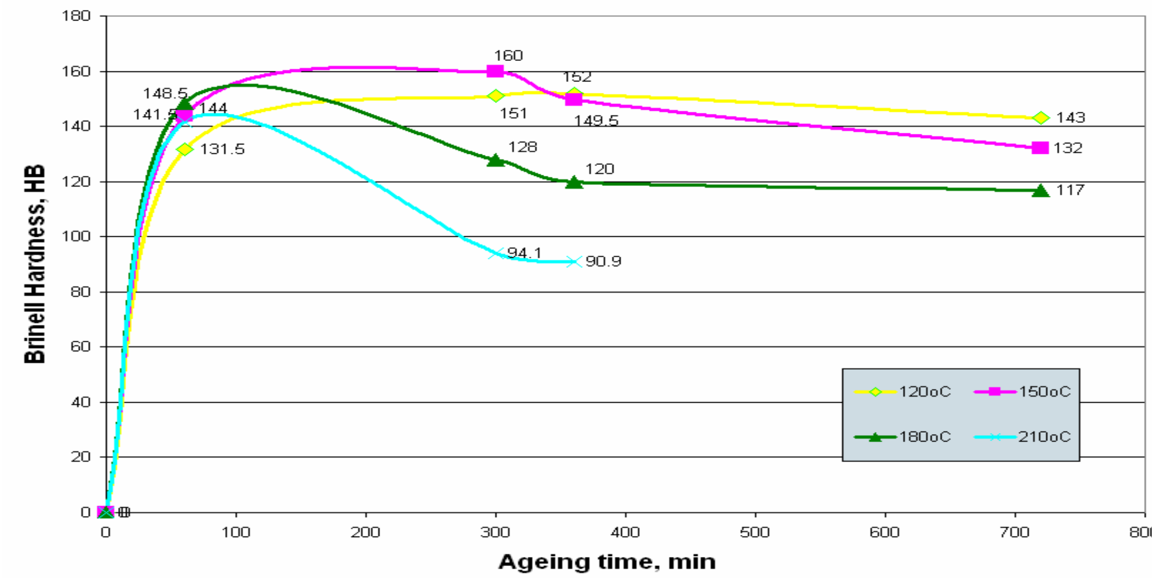


Fig. 1 The Brinell Hardness variation depending on different temperatures (120-210°C), and different times of aging (60-720 min)

The microstructures of heat treated Al-Zn-Mg alloys are presented in Figures 2. At analysis of microstructures in correlation of Brinell Hardness variation, show that as temperature and the duration of aging increases, we reached the maximum hardness (fine precipitates occured), and after that, the hardness decrease as a result of appearance of coarse precipitates. This phenomenon is explained by the development process of coalescence on downward curve of the variation hardness diagram. According with Fig. 1 we observe that as the aging temperature increases, decreases the time of aging which the material presents maximum values of hardness.

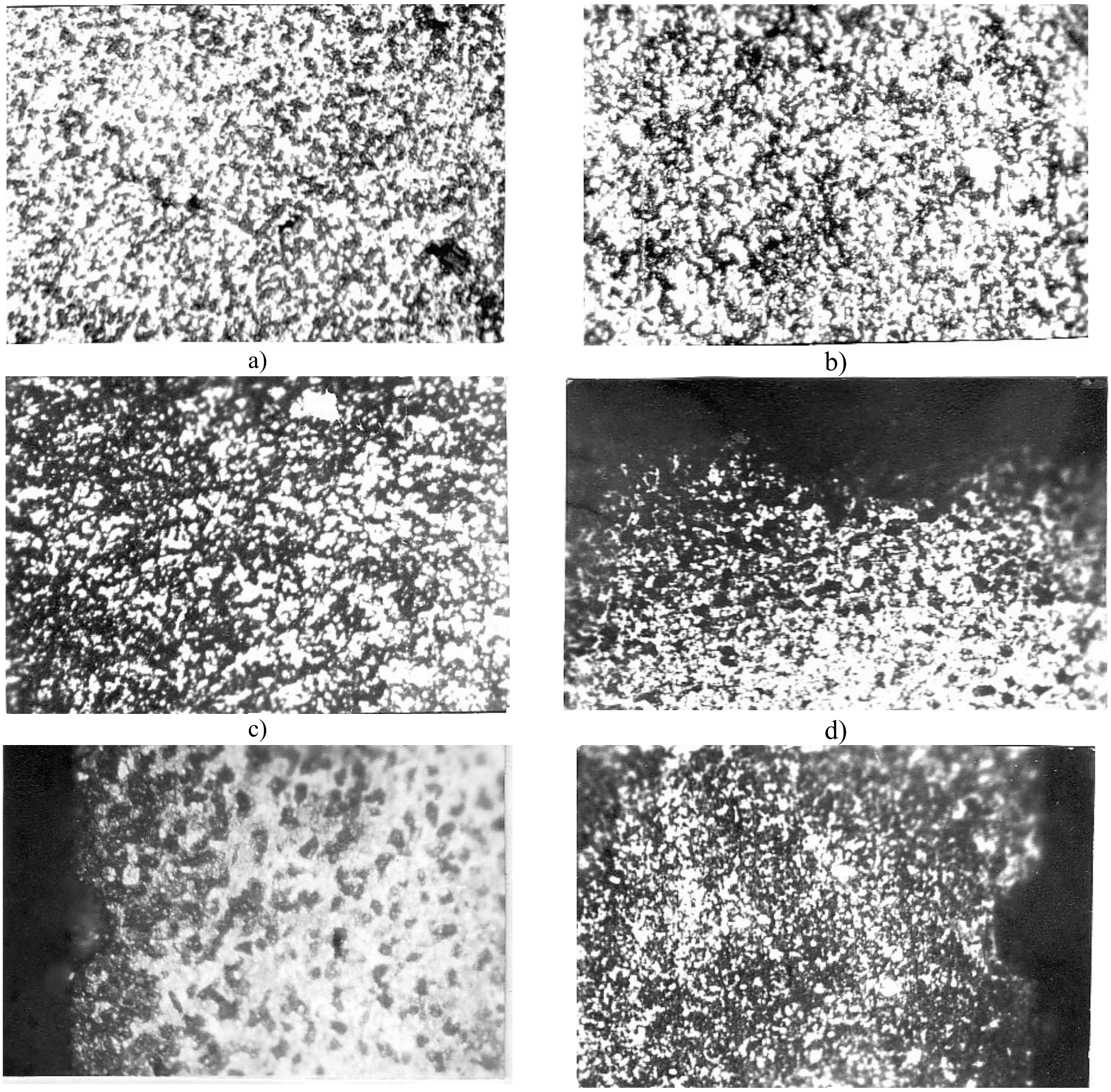


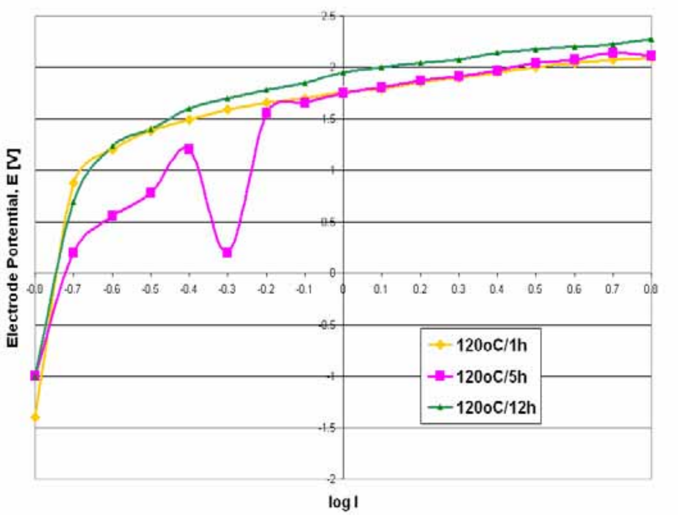
Fig. 2 The microstructures of heat treated Al-Zn-Mg alloys solution treated at 475±5o C for 60 minutes, quenched in warm water (40-60oC) and then artificial ageing at 210°C and different ageing duration
(a, b) 60 min, (c, d) 300min ; (e, f) 540 min ; x 200 magnification

In Fig 4 are shown the polarization curves (the current density I [mA] as function of electrode potential E [V]) for Al-4Cu-1,5 Mg –Mn solution treated at 475±5°C for 60 minutes, quenched in warm water (40-60°C) and then artificial ageing at 60-720 minutes. The polarization curves were made under a constant aging temperature and different duration of aging (Fig. 3 a-e) and also for different aging temperatures (120, 150, 180 and 210°C) and at 300 minutes maintaining time of aging (Fig. 4). Analyzing the structures from Figures 2 we notice that there is a corrosion layer with separation of cavities forming material and corrosive.

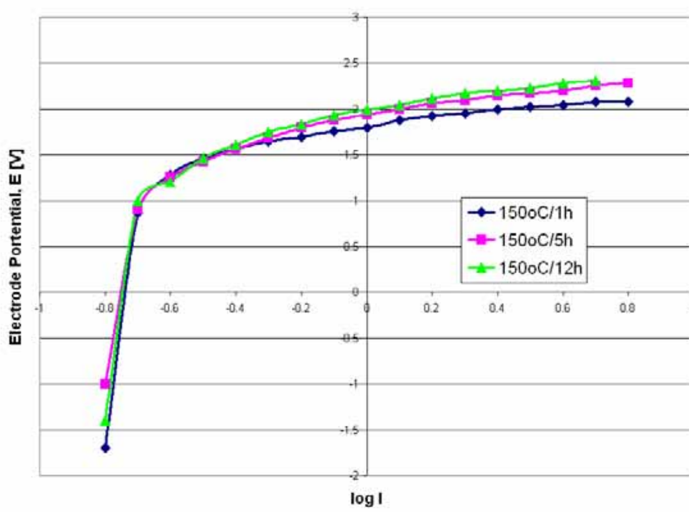
It is observed that with increasing duration of aging, the corrosion resistance decreases.

4. Discussion

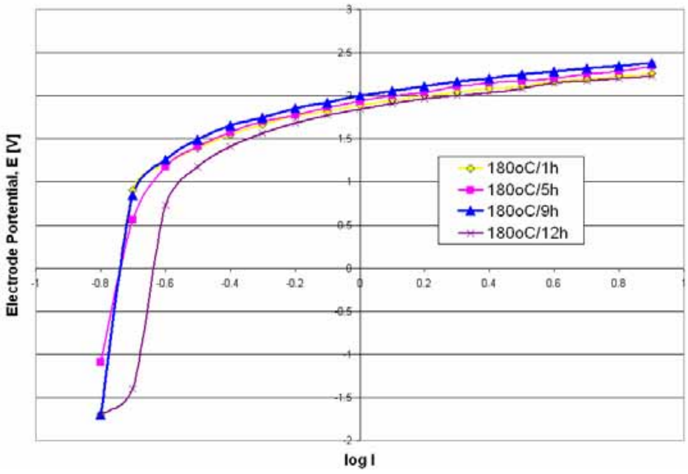
We can see also that the required hardness and the stability in time of this hardness are ensured at 150 ºC/300 minutes artificial aging. Analysis of microstructures presented in Fig. 2 (d, e and) in correlation of Brinell hardness variation , show that as temperature and the duration of aging increases, we reached the maximum hardness (fine precipitates occured), and after that, the hardness decrease as a result of appearance of coarse precipitates. This phenomenon is explained by the development process of coalescence on downward curve of the variation hardness diagram.



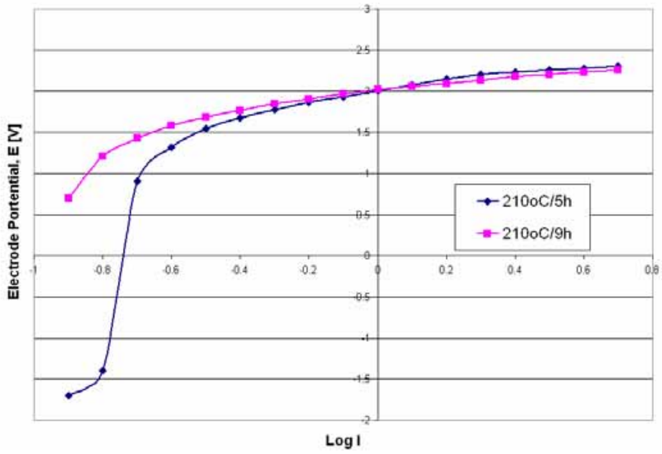
a)



b)



d)



e)

Fig. 3 Polarization curves for Al-Zn-Mg-Cu solution treated at 475±5°C for 60 minutes, and then artificial ageing at (a) 120°C; (b) 150°C ;(c) 170 °C (d) 210 °C and different duration of aging (between 60-720 min)

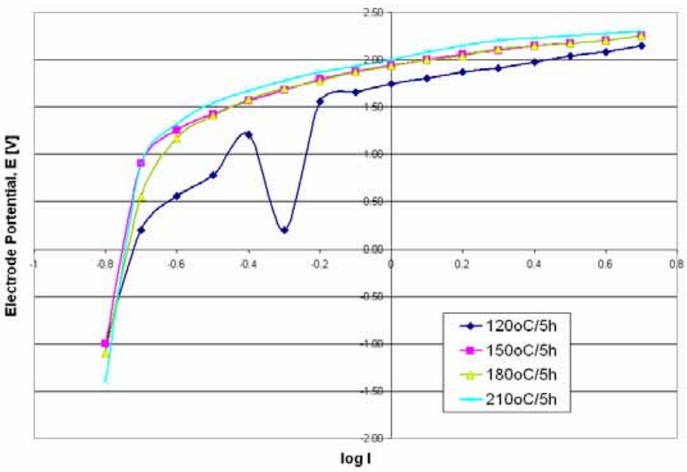


Fig.4 Polarization curves for Al-Zn-Mg-Cu heat treated at different ageing temperature and mentained at same aging time (300 minutes)

Aging curves show that the effect of hardening occurs during the formation of coherent precipitates (Guinier Preston zone), but that it decreases the occurrence of incoherent precipitates. Intercrystalline corrosion is the electrochemical corrosion which taking place at the boundary secondary phase. The intercrystalline corrosion is explained as follows: by reducing of solid solution between the secondary phase and solid solution appears a potential difference and forming a galvanic micro-cell. After analysis of polarization curves we can observed first: an active process, in which, corrosion current intensity increases over a small range of potential. After this zone, metallic material enter in a passivation zone, zone characterized of a small change in current intensity within a high potential. In the passive corrosion zone the process takes place more slowly than in the active zone. From Fig. 3 we observed that with increasing aging time, the modification process from passive to active one is carried out at current density becoming mach smaller.

Conclussion

Following experimental data obtained, it is noted that in terms of microhardness the best behavior is at 150°C during 300 minutes, followed by the values of hardness obtained at ageing parameters of 120°C to 300 minutes. In terms of corrosion we observe that the Al-Zn-Mg-Cu alloys sample tested at artificial ageing at 120°C with to 300 minutes, the obbtained results are not so good.
For aging temperature of 180°C and 210°C we are found that maximum hardness is obtained at lower aging times. From corrosion point of view we observed that the behavior of all analyzed samples are similarly.

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