INFLUENCE OF HEAT TREATMENT ON THE MICROSTRUCTURE AND HARDNESS OF THE EN AW-7075 ALUMINIUM ALLOY

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Abstract

An experimental investigation was carried out on the commercial aluminium alloy EN AW-7075. The study included changes in the microstructures as well as the changes in hardness during heat treatments. Heat treatment conducted in this paper included annealing, solution heat treatment at 480°C for one hour, quenching in ice water in order to obtain the super saturated solid solution and after that artificial aging at different temperature (110°C-250°C) for 30 minutes. After each heat treatment measurements were taken and analyzed. Hardness and microstructural changes were investigated as a function of aging temperature (isochronal aging). Obtained results show an increase in hardness values with the increment of aging temperature due to the precipitation hardening that this alloy possesses. This increment in hardness is also confirmed by the optical microscopic analysis and obtained microstructures that show precipitation of metastable η` phase.

Introduction

Aluminium alloys from 7000 series are used in many industrial fields, especially in structural applications, automotive and aerospace industry, because of their high strength and low density [1-6]. The EN AW-7075 alloy has three main alloying elements: zinc, magnesium and copper. This aluminum alloy is very susceptible to various heat treatments. The most used heat treatment on these types of alloys is precipitation hardening or age hardening (T6 process). This process is known to enhance mechanical properties to those alloys that are sensitive to this type of heat treatment as EN AW-7075 alloy is due to the high solubility of Zn and Mg in aluminium [7-8]. In order to achieve the enhancement of mechanical properties, some steps in the heat treatment must be completed, this includes: solution heat treatment, quenching to room or below room temperature and aging, which can be either natural (performed at room temperature) or artificial (performed at higher temperatures). The aging process is responsible for the formation of very fine and evenly dispersed particles in grains and grain boundaries that hinder the movement of dislocation thus strengthening the alloy [1]. The largely accepted precipitation sequence for Al-Zn-Mg-Cu alloys is [2, 4, 6, 7]: Supersaturated solid solution → GP zones → metastable η` (MgZn2) phase → stable η (MgZn2) phase. In the reviewed literature, the aging process is defined primarily by aging temperature and time. Thus, our investigation was focused on the influence of isochronal artificial aging on mechanical and structural properties of EN AW-7075 alloy. Our aim was to define the isochronal aging regime that included short aging periods in a wide temperature range.

Experimental

Experimental investigation was performed on EN AW-7075 aluminum alloy. The alloy was received in aged condition in the form of rounded bar with diameter of 20 mm. Manufacturer guarantees composition of the alloy which is given in Table 1. In order to remove "as fabricated" state, all of the samples were subjected to annealing at 480°C for 3 hours in the electric resistance furnace „Vims elektrik LPŽ-7,5 S" and obtained Temper O. Solution heat treatment was performed at the temperature of 480°C for 1 hour followed by quenching in water with ice in order to obtain a super saturated solid solution α_{ssss} (Temper W) Quenched samples were subjected to isochronal aging at different temperatures ranging from 110°C to 250°C for 30 minutes (Temper T6/T7). This investigation included changes in the hardness, as well as microstructural changes during heat treatment. „Innovatest IT5350" Leeb hardness tester was used for hardness measurements, all according to ASTM A956 standard.

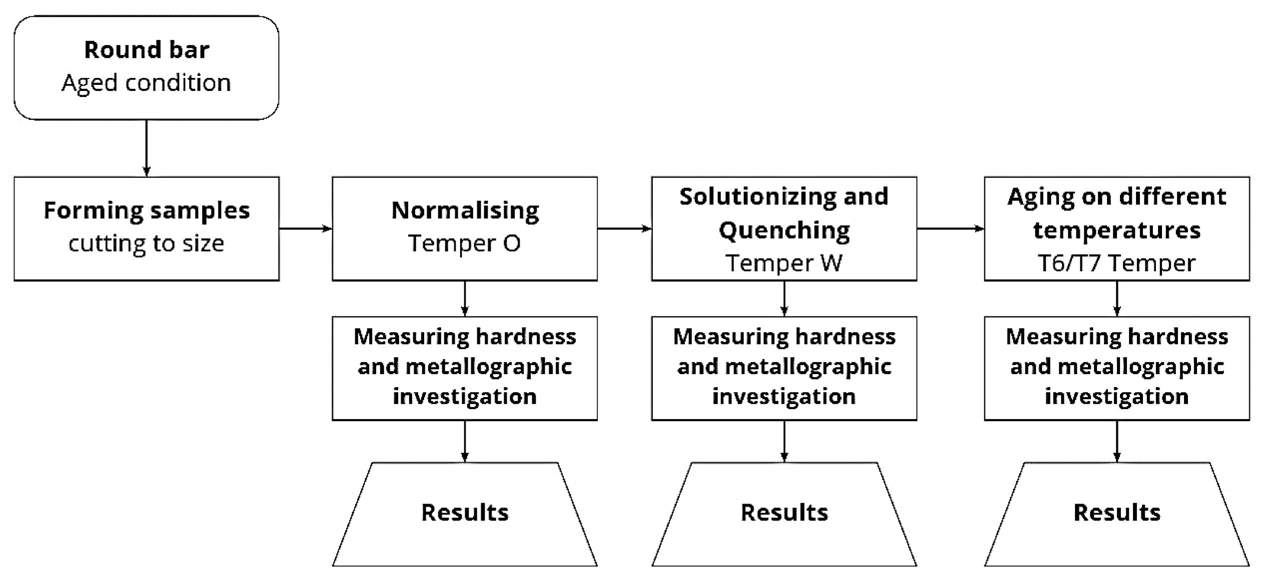

Table 1. Chemical composition of the investigated alloy

Element	Zn	Mg	Cu	Si	Fe	Mn	Other	Al
Range (%mass.)	5.1-6.1	2.1-2.9	1.2-2.0	0.4	0.5	0.3	0.4	Rem.

Figure 1. Used equipment: a) Furnace „Vims elektrik LPŽ-7.5 S"; b) „Innovatest IT5350" Leeb hardness tester; c) Carl Zeiss Jena "Epytip 2"Microscope

Results and discussion

Aging at 110°C immediately caused hardness values to increase from 330 HLD for quenched condition to 420 HLD (Fig.2.), which is a proof that this alloy has a high sensitivity to aging treatment even on very low temperatures. The hardness gradually increases until it reaches a maximum at 150°C, where hardness has a value of 430 HLD. The increase in hardness values can be ascribed to the formation of GP zones, coherent with the matrix and semi-coherent metastable η' phase. Dislocations move and cut through the formed phases, which is why surface energy increases and the kinetic energy of the dislocations are consumed, so the mechanical properties increase [2]. After reaching the maximum, hardness values gradually decrease due to overaging. Overaging is followed by coagulation of the η' phase, disappearance of GP zones and gradual formation of the stable η phase. With overaging and formation of the incoherent precipitate of η phase, lattice distortions are lowered and the particles lose their critical size so dislocations can now move more easily causing the decrease in hardness values [3, 7].

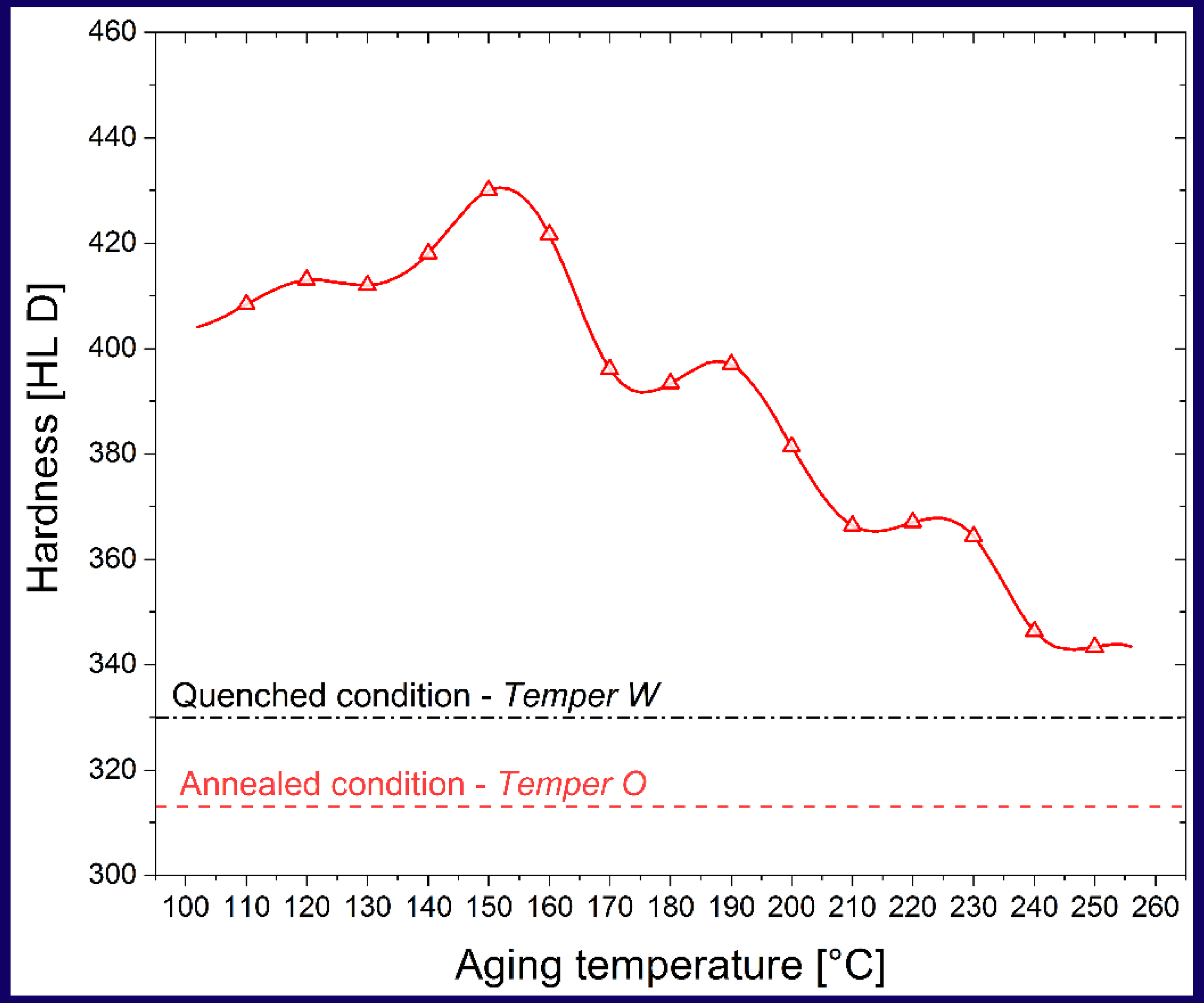

Figure 2. Hardess as a function of aging temperature

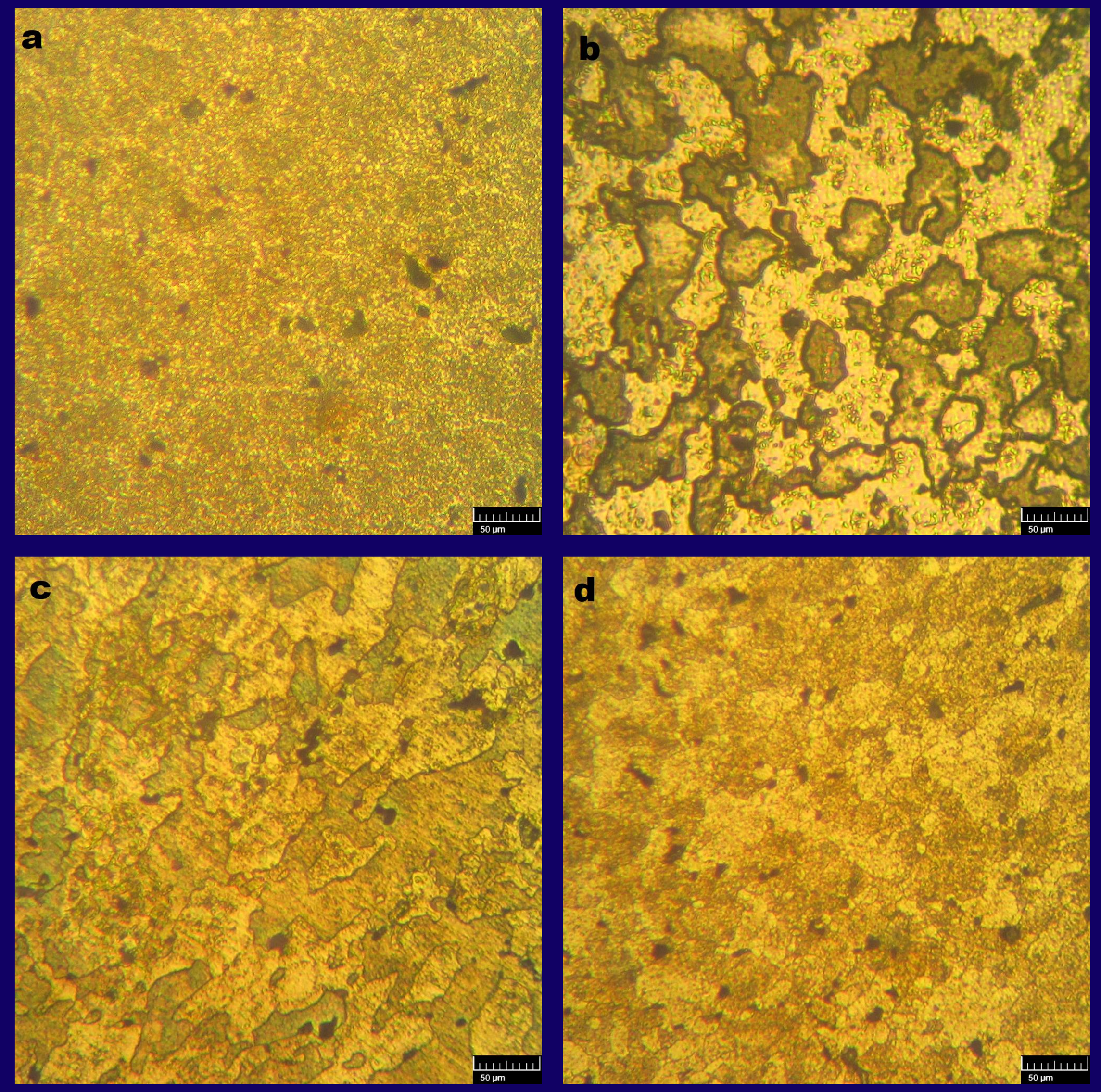

Figure 3. Microstructures of the EN AW-7075 alloy after different heat treatments: : a) after annealing; b) after quenching; c) after aging at 150 °C; d) after aging at 240 °C

The microstructure of annealed sample is presented in Fig. 3a and it has yielded the lowest value of hardness, which is to be expected because the microstructure mostly consists of the stable η phase [4]. Fig. 3b represents the as-quenched state which yielded somewhat higher values of hardness mostly due to quenched-in vacancies that hinder movement of dislocations. Microstructure of the samples with highest values of hardness is represented by Fig. 3c. When comparing it with the Fig. 3a and 3b it can be seen that there are dispersed particles throughout the whole microstructure. It is believed that fine particles are the η` metastable phase that responsible for the high values of hardness. In Fig. 3d the overaged state can be seen, which yielded very low hardness, close to the values of annealed sample, due to the formation of the stable η phase and cogulation of other present phases.

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