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RESEARCH ARTICLE - ENGINEERING

Formability, Mechanical and Chemical Properties Assessment for High Strength AA7075 Subjected to Annealing Heat Treatment

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Abstract

The current study examined how the annealing process affected the formability, mechanical and chemical characteristics of 7075 alloy. The formability was achieved during the bending test. Tensile, hardness, microstructure and corrosion tests represent mechanical and chemical properties. The test specimens for each test were prepared then followed by annealing heat treatment by heating them to 200 and 300°C in an electrical furnace for two hours. Then, the specimens were allowed to cool in the furnace to a room temperature. The results indicate that the tensile strength and hardness were decreased for about 50%. Bending strength was increased by approximately 30%, where the specimens bent at a very high angle without cracking or breaking in comparison to base metal. Annealing heat treatment with a proper selected procedures and temperatures was able to stabilize the microstructure and release the second phase precipitate particles. Annealing process contributed in improving formability, ductility and corrosion resistance of the Al 7075 alloy.

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1. Introduction

Aluminum alloys are utilised for various applications because of their unique properties such as corrosion resistance, low density, high ductility, adequate high strength, high reflectivity and low cost. They possess a useful combination of ductility and strength and are non-toxic and recyclable [1, 2]. The major alloying elements of the precipitation-hardening aluminum alloy AA7075 are Zinc (5.1-6.1 wt.%), Magnesium (2.1-2.9 wt.%), and Copper (1.2-2.0 wt.%). Due to their very high strength to weight ratio, the AA 7075 alloy is widely utilized in the structural components of aircraft and the automobile industry [3-5]. Since Al 7XXX series is a heat-treatable alloy, and in order to enhance the formability and ductility, and to stabilize the microstructure of the Al 7075 alloy, a proper and effective annealing treatment is required and very important [3, 5, 6]. Three different types of second phase particles, including (intermetallic particles made from elements like Zr, Cr, and Mn), constituents (Fe or Si impurities, or excessive amount of major elements), and strengthening precipitates ($MgZn_2$) can be found in the microstructure of the AA 7075 [5, 7]. When this alloy properly annealed, the microstructure may be stabilized, and thesecond-phasee precipitates may be released from the matrix. It is very important to understand how the second phase particles effect the recrystallization of this alloy. Using second phase particles as a mean of regulating size and texture of the grains during thermo mechanical processing requires a full understanding of the influence of them on annealing behavior [7, 8]. However, the deformation heterogeneities at large particles may be the spots at which the recrystallization may commence during the annealing of materials with high alloying content. For instance, particles closely spaced might pin the grain boundaries [9-11].

Chemical characteristics for AA 7075 can be represented by the corrosion test. The most frequent type of corrosion that effects aluminum is known as "pitting", and it typically takes the appearancea of haphazard pit formation. Different alloys are impacted differently depending on their composition and external factors [11]. Because pitting results from a galvanic interaction between various components on the alloy, the purer the alloy is, the higher pitting resistance it possesses in general. Due to its capacity to pierce the metal to its depth, which causes greater stress concentrations at these spots, it is frequently the most harmful type of corrosion.

Nomenclature

XRD	x-ray diffraction	B	specimens heated to 300 °C
OCP	potential cell current	WE	working electrode
Ecorr	corrosion potential	Icorr	corrosion current
SCE	Calomel electrode	A	non-treated specimens

The exposed metal readily releases electrons as the oxide layer breaks down, and the reaction starts small pits with confined chemistry that support an immediate attack. The pit will spread as a result of this attack.

Researchers have worked on heat treatment of AA 7075. Panigrahi and Jayaganthan [3] studied the effect of cryorolling for AA 7075 followed by annealing treatment. They found that the tensile strength and hardness of the CR Al 7075 alloys reduced during the annealing treatment process from 150 to 250°C and for subsequent it remains constant. Rao *et al*. [4] investigated cold rolling and annealing treatment for Al 7075 alloy at a range of 225-325°C. They found that cold rolling increased yield strength and lowered the ductility, while subsequent annealing at high temperatures increased elongation values and formability.

The purpose of the current research is to investigate and define a proper annealing heat treatment procedure for AA 7075 and their effect on the formability and ductility, mechanical, and chemical properties.

2. Experimental work

The selected alloy is Al 7075-T6. Using the ARL spectrometer to analyze the chemical composition, Table 1 shows the results.

Table 1. Chemical Composition of AA 7075 (wt.%) [12]

Element wt.%	Cr	Mg	Si	Fe	Cu	Mn	Ni	Ca	Zn	Ti	Al
Actual value	0.21	2.43	0.088	0.16	1.431	0.065	0.006	0.008	5.58	0.04	Rem.
Standard value [11]	0.180-0.28	2.11-2.9	0.40	0.50	1.2 -2	0.30	0.05	0.06	5.1-6.1	0.040	Rem.

2.1. Preparations of specimens

In compliance with the ASTM (A370-11) standard, the tensile test specimens produced in a circular cross section with the required dimensions. Bending test specimens with typical dimensions that meet ASTM (E 190-92) specifications were made. Finally, according to ASTM (G 70-30) standards, specimens for corrosion test with dimensions of 15 mm diameter, and 3 mm thickness produced from studied alloy. The produced specimens for all tests were split into three groups, the symbol (A) being given to specimens that were not exposed to annealing heat treatment, and the symbols (B and C) being given to specimens that were heated to 200, and 300°C consequently, submerged at this temperature for two hours and then left to cool down in the furnace to room temperature to complete the annealing process.

2.2. Microstructure test

To investigate the microstructural characteristics of each sample, preparations were made to specimens. The specimens were grinded by Emery sheets with mesh sizes of 400, 800, 1200, and 2000 and then polished by 2μm Diamond paste. Etching was done for about 30sec. in Keller's Etch. Microstructure tests were carried out using an optical microscope with a camera connected to a computer. The obtained pictures are as shown in Fig. 1.

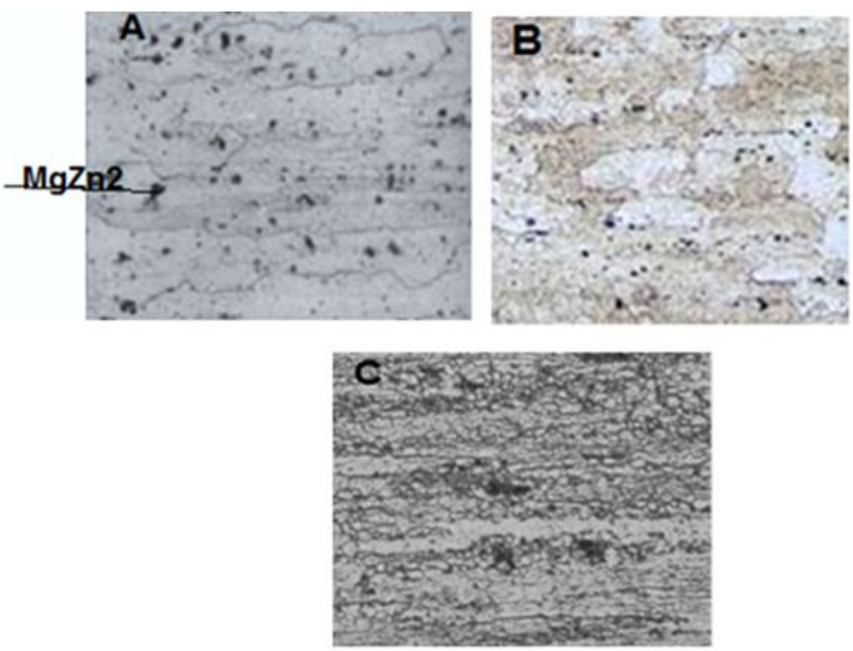

Fig. 1. Microstructure test for specimens A, B, and C at 100x

2.3. X-ray diffraction test

The results of XRD tests for AA 7075 annealed at different temperatures are shown in Fig. 2. Precipitate peaks of $MgZn_2$ are not observed in sample A, whereas very small intensity peaks observed at an annealing temperature of (200°C), and their intensity increase with increasing of annealing temperature.

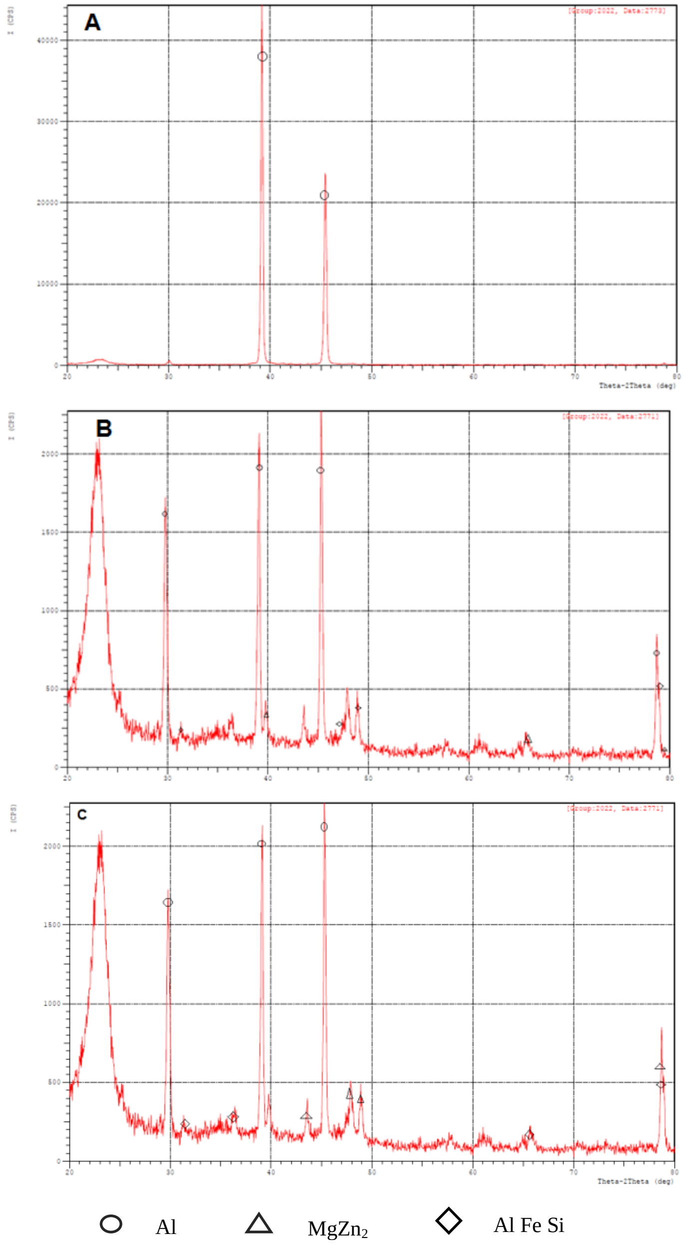

Fig. 2. X-Ray Diffraction results for specimens A, B, and C

2.4. Tensile test

Three specimens, shown in Fig. 3, were tested for each heat-treated group and also for as received material. Using a computerized Instron 3369 electromechanical testing machine, the tests were conducted at a room temperature with a crosshead speed of 0.5 mm/min. Yield, Ultimate tensile strength and percentage elongation data were derived. The three tests average values are provided in Fig. 4 and Table 2.

Fig. 3. Tensile test specimen

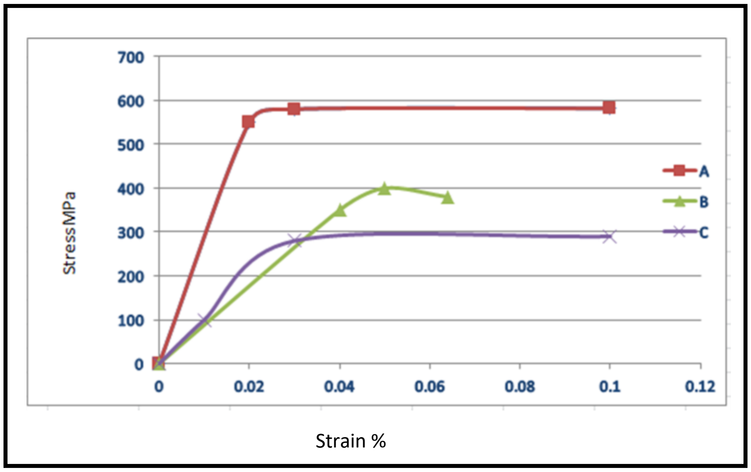

Fig. 4. Stress-strain curves for specimens A, B, and C

Table 2. Yield and ultimate tensile results for specimens A, B, and C

Specimen	A	B	C
Yield strength (MPa)	530	360	265
Ultimate strength (MPa)	585	405	297

2.5. Bending Test

It occurs practically in all forming processes and is the most prevalent type of deformation. To establish how simply sheet metal can be produced, a bending test is required. At room temperature, exterior face bending investigation is performed using three points method. Bending specimen is shown in Fig. 5 before and after conducting the test. At a 3.5 mm/min speed, the test was conducted using a 100kN Universal machine to determine the specimens' bending strength. The results are shown in Fig. 6.

2.6. Hardens test

The Rockwell B hardness test was used to evaluate the hardness of the specimens. Hardness test location was measured perpendicular to the longitudinal axis. The average hardness is determined by three separate measurements made at various randomly chosen spots, and the results is shown in Table 3.

Fig. 5. Bending test specimen

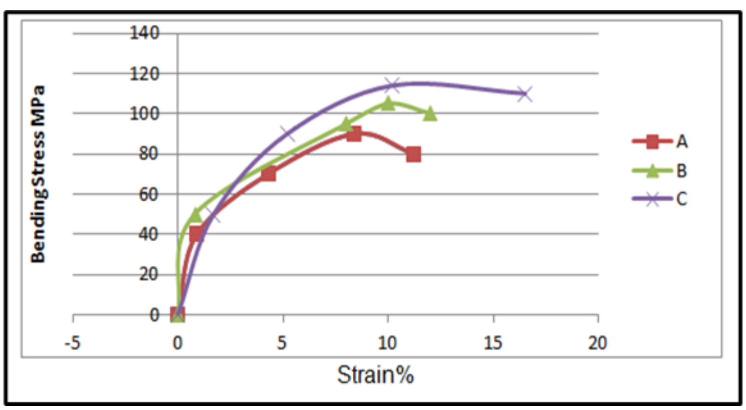

Fig. 6. Stress-strain curve for bending test for specimens A, B, and C

Table 3 Rockwell B hardness results for specimens A, B, and C

Specimen	A	B	C
Hardness Kg/mm^2	87	55.4	43.5

2.7. Corrosion test

The holder was filled with the fitted exposed area specimen (1x 1 cm^2). Corrosion tests were done using a Wenking Mlab multi-channel powerful dynamic and SCI-Mlab corrosion measuring system from Bank Electronics-Intelligent control GmbH, Germany. During a quick, gradual sweep from -1000 to +1000 mV relative to the potential cell, the potential cell currents were recorded (OCP). The potential sweep's speed is expressed in mV/sec by scan rate (10 mV/ sec). On the other side of the voltage curve, the current density is essentially linear in magnitude. In this experiment, the specimens were used as working electrodes (WE), the Calomel electrode (SCE) served as the study's reference electrode, while the auxiliary electrode was a platinum-type electrode. All specimens were submerged in a sodium chloride solution at 3.5 wt.% NaCl with a PH of 6.9 to identify corrosion factors such as corrosion potential (E_{corr}) and corrosion current (I_{corr}) at each time, as indicated in Fig. 7 and Table 4 for specimens A and B as an example.

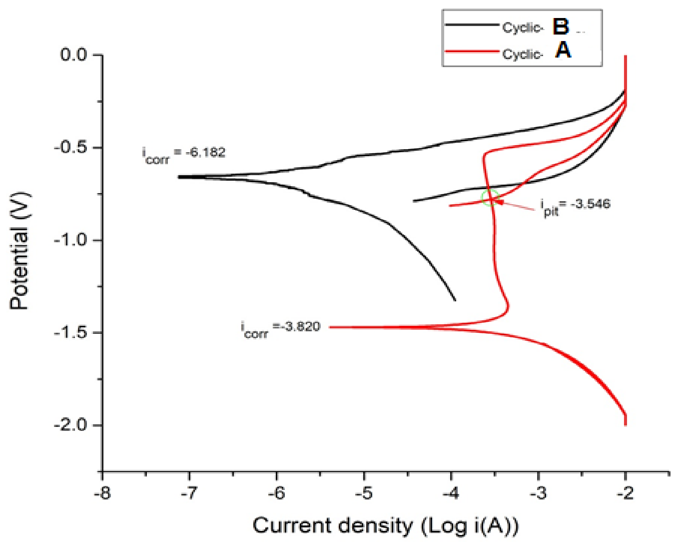

Fig. 7. Corrosion results for specimens A and B

Table 4 Result of Corrosion test for A and B

Specimens	I_{corr}. A/Cm^2	I_{Pit}. A/Cm^2	Corrosion rate m.p.y
A	1.51E-04	2.84E-04	6.493
B	6.57E-07	------------	1.528

3. Results and Discussion

The heat treatment process, known as annealing, at 200 and 300℃ effect on microstructure, mechanical, and chemical properties of AA 7075 was investigated. The grain structure of the base AA7075 aluminum alloy is represented in Fig. 1(A), which simply demonstrates the elongated pancake-shaped grains with precipitates ($MgZn_2$). In Fig. 1 (B), when this material is properly annealed, the microstructure was stabilized and the second phase precipitates were released from the matrix due to recrystallization process. In order to study how annealing effected the mechanical characteristics of AA 7075 that causes increase in the ductility and bending for about 30%, and decreases the yield strength, ultimate tensile strength, and hardness by about 50%, as shown in Figs. 4 and 6, and Tables 2 and 3. This suggests that at these temperatures, recrystallization happens quickly due to incoherency with the matrix, the precipitate particles lose their ability to harden. This obviously proves that the recrystallization process has ended at (300℃). Mechanical properties show that the kinetics of recrystallization follow the same pattern as those of microstructural progression.

How ductile a material is, can be determined using the bending test. Bending test is essential for determining the formability of sheet metal since bending test is the most frequent type of deformation and occurs in practically all forming operations and can describe the failure mechanism [12]. Bending tests showed that ductility and formability increased for about 30% with annealing treatment, see Figs. 5 and 6.

Pitting corrosion was discovered to be the most common type of localized corrosion upon examination of corroded surfaces. Despite the fact that they began to form on the first cycle, the commencement of pits is limited to a very small number of sites. Due to the interaction of aluminum, a particularly active metal, with the other alloying elements, which results in an oxidation-reduction reaction, the alloy composition and microstructure can have a significant impact on the potential for an alloy to pit. Pitting is also caused by the constituent particles that various alloying elements create. While other particles worked as anodes, dissolving themselves, some particles acted as cathodes, boosting the matrix's dissolution around them. The deterioration of the samples along the corrosion process for each condition variation investigated is shown in the following subsections, Fig. 7 and Table 4. There are pertinent statistics for each extraction point inside each instance.

4. Conclusions

- Annealing heat treatment with a proper selected procedures and temperatures was able to stabilize the microstructure and release the second phase precipitate particles.
- Mechanical properties, Strength and hardness, were shown to be decreased for about 50% with annealing treatment.
- Formability and ductility were shown to be increased for about 30% with annealing treatment.
- Corrosion exposure to salt fog leads to extensive pitting of the not anodized material from the first cycle.
- Increased corrosion was present on the edges of the exposed surface

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