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STUDY OF HEAT TREATMENT INFLUENCE ON ALUMINUM -BASED ALLOY ATN-Si10Cu4

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ABSTRACT

This work presents the experimental results concerning the behavior on heat treatment of on aluminum based alloy. The laboratory level experiments achieved on samples of ATN-Si10Cu4 (4145 series) alloy illustrate the variation of properties depending on the variation of heat treatment technological parameters specific to different heat treatment. We have experimented more variants of heat treatment in order to establish the optimal variant treatment. The samples were characterized by HB hardness and microstructure analysis.

KEYWORDS: heat treatment, quenching in solution and heat ageing, aluminum based alloy.

1. Introduction

ALUMINUM, the second most plentiful metallic element on earth, became an economic competitor in engineering applications as recently as the end of the 19th century. It was to become a metal for its time. The emergence of three important industrial developments would, by demanding material characteristics consistent with the unique qualities of aluminum and its alloys, greatly benefit growth in the production and use of the new metal.

The properties of aluminum that make this metal and its alloys the most economical and attractive for a wide variety of uses are appearance, light weight, fabricability, physical properties, mechanical properties, and corrosion resistance.

Aluminum has a density of only 2.7g/cm^3. It can display excellent corrosion resistance in most environments, including atmosphere, water, petrochemicals, and many chemical systems. Aluminum surfaces can be highly reflective. Aluminum typically displays excellent electrical and thermal conductivity, but specific alloys have been developed with high degrees of electrical resistivity. It is nonferromagnetic, a property of importance in the electrical and electronics industries [1, 2, 3, 4, 5, 6].

It is convenient to divide aluminum alloys into two major categories: casting compositions and wrought compositions. A further differentiation for each category is based on the primary mechanism of property development. Many alloys respond to thermal treatment based on phase solubilities.

These treatments include solution heat treatment, quenching, and precipitation, or age, hardening. For either casting or wrought alloys, such alloys are described as heat treatable. A large number of other wrought compositions rely instead on work hardening through mechanical reduction, usually in combination with various annealing procedures for property development (Fig.1). These alloys are referred to as work hardening. Some casting alloys are essentially not heat treatable and are used only in as-cast or in thermally modified conditions unrelated to solution or precipitation effects [1, 2].

1*xxx* Series. Aluminum of 99.00% or higher purity has many applications, especially in the electrical and chemical fields. These grades of aluminum are characterized by excellent corrosion resistance, high thermal and electrical conductivities, low mechanical properties, and excellent workability. Moderate increases in strength may be obtained by strain hardening. Iron and silicon are the major impurities. Typical uses include chemical equipment, reflectors, heat exchangers, electrical conductors and capacitors, packaging foil, architectural applications, and decorative trim.

2*xxx* Series. Copper is the principal alloying element in 2*xxx* series alloys, often with magnesium as a secondary addition. These alloys require solution heat treatment to obtain optimum properties; in the solution heat-treated condition, mechanical properties are similar to, and sometimes exceed, those of lowcarbon steel. In some instances, precipitation heat treatment (aging) is employed to further increase mechanical properties.

This treatment increases yield strength, with attendant loss in elongation; its effect on tensile strength is not as great.

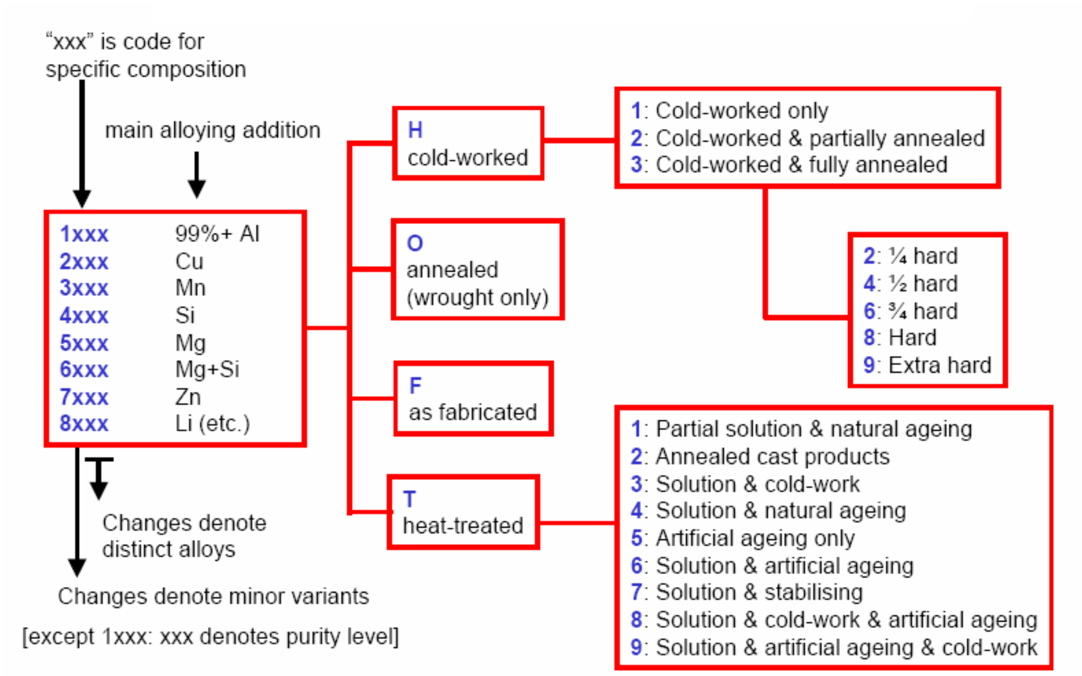

Fig.1. *Al alloys and treatment classification system*

Table 1. *Characterization of aluminum based alloys*

Alloy series	Composition	σ_c [MPa]	σ_r [MPa]	ε [%]	Notes
1000	Pure Al	30 - 100	100 - 135	Up to 50	Foil, decoration, electrical conductors
2000	~4.5%Cu (+Mn, Si, Mg) age - hardened	Up to 480	Up to 520	5 - 20	General purpose forgings and extrusions, esp.airframes
3000	~1%Mn, Mg cold - worked	Up to 215	Up to 290	5	Ductile sheet for cladding trucks, trailers; food containers, drink cans.
4000	12%Si (+Mg, Ni, Cu) forgeable, age - hardened	~295	~325	0.5	IC engine pistons
5000	~5%Mg (+Cr, Mn)cold - worked	Up to 350	Up to 415	15	Good formability and weldability; excellent corrosion resistance; structural applications, esp. marine.
6000	Up to 1% Mg – Si, age - hardened	~275	~310	12	Hot extrusions; window frames.
7000	Up to 8% Zn (+Mg, Cu, Cr) age - hardened	500	575	11	Highest strength alloys; aircraft structures.
8000	Other, e.g. up to 2.5% Li				Novel and specialist alloys
Cast	Near Al – 13%Si eutectic + 0.01% Na	Up to 200	Up to 300	2 - 5	Automotive castings; can age – harden if Cu and Mg added.

The alloys in the 2*xxx* series do not have as good corrosion resistance as most other aluminum alloys, and under certain conditions they may be subject to intergranular corrosion. Therefore, these alloys in the form of sheet usually are clad with a high-purity aluminum or with a magnesium-silicon alloy of the 6*xxx* series, which provides galvanic protection of the core material and thus greatly increases resistance to corrosion. Alloys in the 2*xxx* series are particularly well suited for parts and structures requiring high strength-to-weight ratios and are commonly used to make truck and aircraft wheels, truck suspension parts, aircraft fuselage and wing skins, and structural parts and those parts requiring good strength at temperatures up to 150 °C (300 °F). Except for alloy 2219, these alloys have limited weldability, but some alloys in this series have superior machinability.

3*xxx* Series. Manganese is the major alloying element of 3*xxx* series alloys. These alloys generally are non-heat treatable but have about 20% more strength than 1*xxx* series alloys. Because only a limited percentage of manganese (up to about 1.5%) can be effectively added to aluminum, manganese is used as major element in only a few alloys. However, three of them--3003, 3X04, and 3105--are widely used as general-purpose alloys for moderate-strength applications requiring good workability. These applications include beverage cans, cooking utensils, heat exchangers, storage tanks, awnings, furniture, highway signs, roofing, siding, and other architectural applications.

4*xxx* Series. The major alloying element in 4*xxx* series alloys is silicon, which can be added in sufficient quantities (up to 12%) to cause substantial lowering of the melting range without producing brittleness. For this reason, aluminumsilicon alloys are used in welding wire and as brazing alloys for joining aluminum, where a lower melting range than that of the base metal is required. Most alloys in this series are non-heat treatable, but when used in welding heat-treatable alloys, they will pick up some of the alloying constituents of the latter and so respond to heat treatment to a limited extent. The alloys containing appreciable amounts of silicon become dark gray to charcoal when anodic oxide finishes are applied and hence are in demand for architectural applications. Alloy 4032 has a low coefficient of thermal expansion and high wear resistance, and thus is well suited to production of forged engine pistons.

5*xxx* Series. The major alloying element in 5*xxx* series alloys is magnesium. When it is used as a major alloying element or with manganese, the result is a moderate-to-high-strength work-hardenable alloy. Magnesium is considerably more effective than manganese as a hardener, about 0.8% Mg being equal to 1.25% Mn, and it can be added in considerably higher quantities. Alloys in this series possess good welding characteristics and good resistance to corrosion in marine atmospheres. However, certain limitations should be placed on the amount of cold work and the safe operating temperatures permissible for the higher-magnesium alloys (over about 3.5% for operating temperatures above about 65 °C, or 150 °F) to avoid susceptibility to stress-corrosion cracking.

Uses include architectural, ornamental, and decorative trim; cans and can ends; household appliances; streetlight standards; boats and ships, cryogenic tanks; crane parts; and automotive structures.

6*xxx* Series. Alloys in the 6*xxx* series contain silicon and magnesium approximately in the proportions required for formation of magnesium silicide (Mg2Si), thus making them heat treatable. Although not as strong as most 2*xxx* and 7*xxx* alloys, 6*xxx* series alloys have good formability, weldability, machinability, and corrosion resistance, with medium strength. Alloys in this heat-treatable group may be formed in the T4 temper (solution heat treated but not precipitation heat treated) and strengthened after forming to full T6 properties by precipitation heat treatment. Uses include architectural applications, bicycle frames, transportation equipment, bridge railings, and welded structures.

7*xxx* Series. Zinc, in amounts of 1 to 8% is the major alloying element in 7*xxx* series alloys, and when coupled with a smaller percentage of magnesium results in heat-treatable alloys of moderate to very high strength. Usually other elements, such as cooper and chromium, are also added in small quantities. 7xxx series alloys are used in airframe structures, mobile equipment, and other highly stressed parts. Higher strength 7xxx alloys exhibit reduced resistance to stress corrosion cracking and are often utilized in a slightly overaged temper to provide better combinations of strength, corrosion resistance, and fracture toughness.

2. Experimental conditions

The experiments have been made on ATN-Si10Cu4 aluminum alloy (4145 series) having chemical composition shown in table 2.

Table 2. *Chemical composition of Al-Si-Cu- Mg*

Cu	Fe	Mn	Ni	Zn	Si	Mg	Pb	Al
4.5	0.93	0.61	0.67	3.0	11.05	0.84	0.102	rest

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The laboratory experiments have been made of the specific heat treatments: quenching in solution and heat ageing with different experimental conditions.

The researches shown the optimal technological parameters into experimental conditions, fig. 2:

- The optimal temperature for quenching in solution;
- Time maintaining at optimal temperature for quenching in solution;
- Optimal time and temperature for ageing.

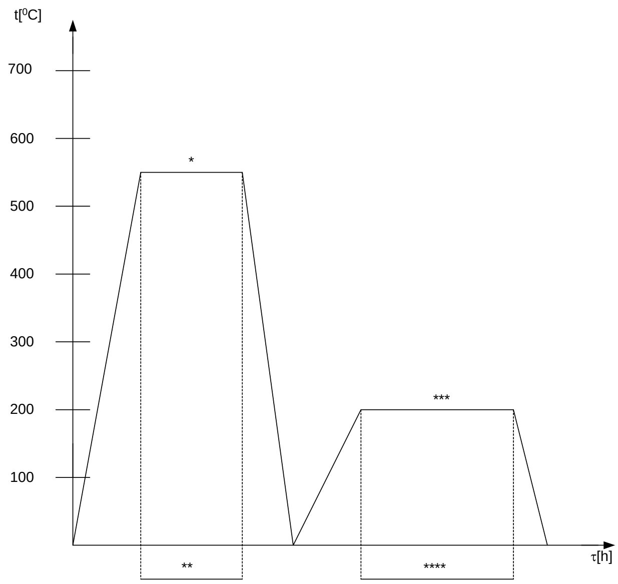


Fig.2. *Experimental conditions for heat treatment: * - temperature for quenching in solution 300°C, 350°C, 400°C, 450°C, 500°C, 550 °C; ** - Time maintaining for quenching in solution, 5 – 8 min/mm in thickness; *** - ageing temperature 120°, 150°, 200°C; **** - Time maintaining 1, 3, 6 ore.*

The effect of heat treatment on alloy structure and physical-mechanical properties was valued by hardness measurements (Brinell method, F=62.5 daN, bowl diameter D=2.5mm, maintaining time τ=15s).

Analyzing this experimental results (Fig.3 and Fig.4) we considered that the optimal temperature is 480 °C and the maintaining time is 2 h.

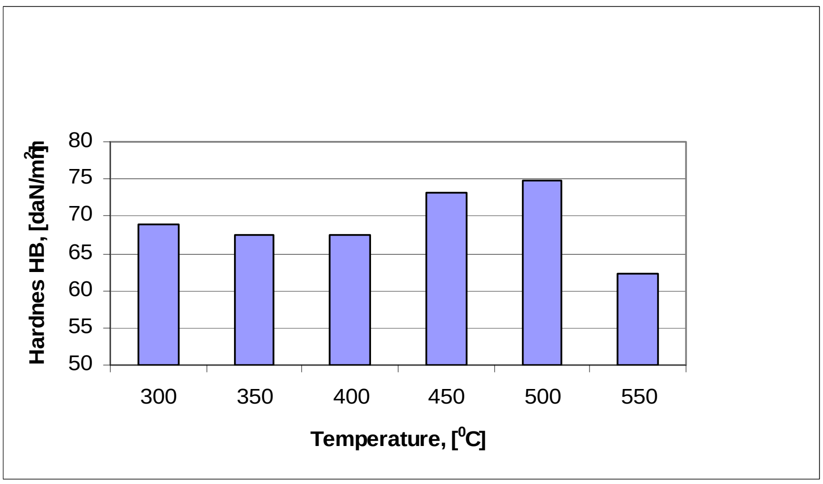


Fig.3. *The influence of quenching in solution temperature on hardness*

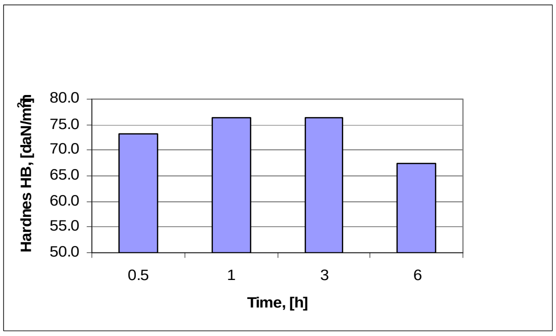


Fig.4. *The influence of time maintaining at 480 °C (optimal one) on hardness.*

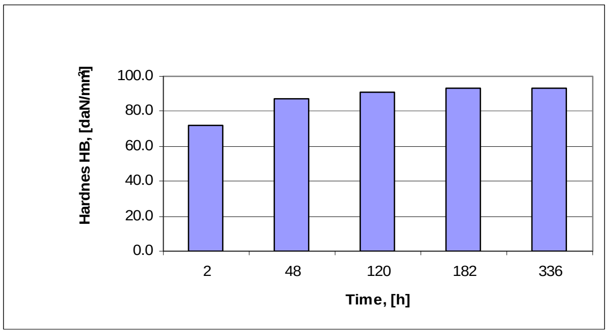
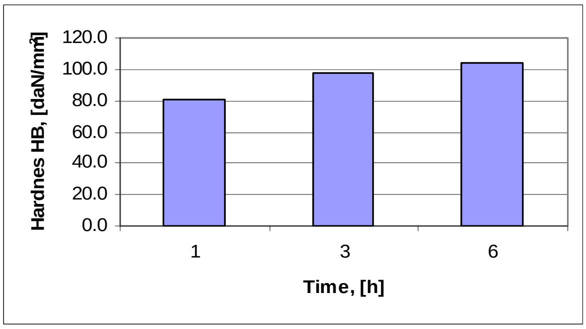
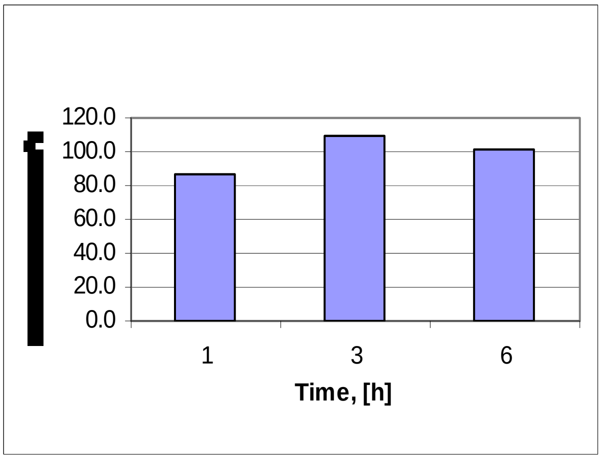


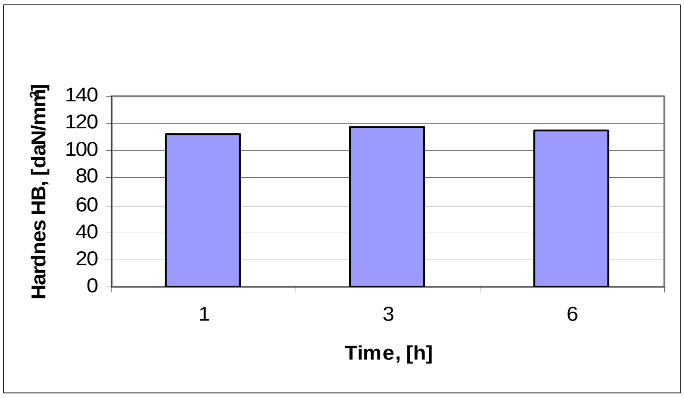
Fig.5. *The influence of time maintaining on alloy natural ageing in state of quenching in solution at 480 °C and 2 h.*



a



b

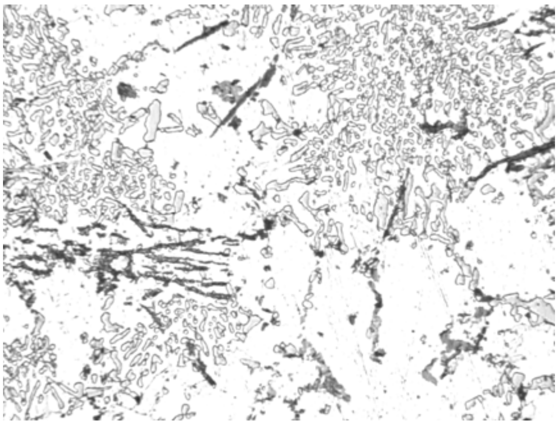


c

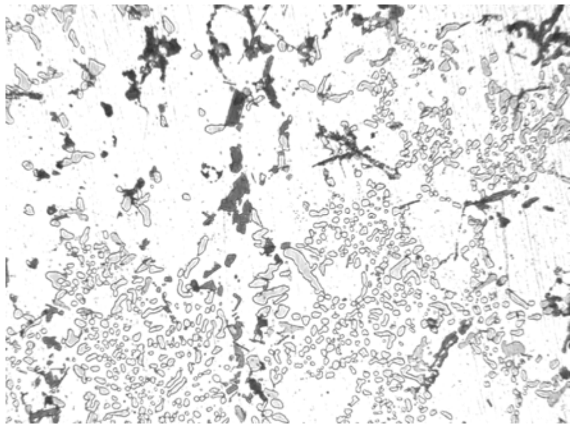
Fig.6. *The influence of time maintaining on alloy artificial ageing at different temperatures:a - 120°C; b - 150°C; c - 200°C.*

3. Microstructural aspects

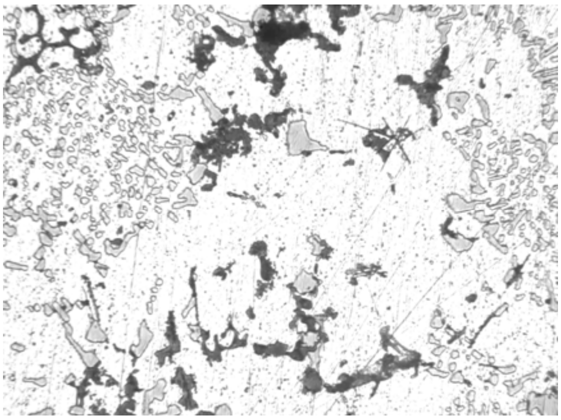
Figure gives the microstructural aspect of the Al alloy to enlargement power 250x, attack with 5% HF.



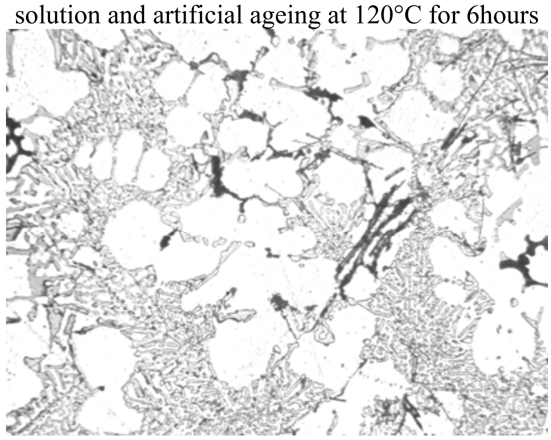
The microstructure of the Al alloy after quenching in solution



The microstructure of the Al alloy after quenching in solution and artificial ageing at 120°C for 6hours



The microstructure of the Al alloy after quenching in solution and artificial ageing at 150°C for 3 hours



The microstructure of the Al alloy after quenching in solution and artificial ageing at 200°C for 3hours

4. Conclusions

The experimental conditions applied shown that this alloy is sensible at structural and properties modifications (considering hardness as a measure for the variation of the mechanical properties).

It was established for the alloy with given chemical composition (table 1) the optimal temperature of quenching in solution - 480 °C for maintaining time 2 hours. The increase of the temperature over this value or the increase of the maintaining time lead to the decrease of hardness. Concerning the heat treatment of ageing it comes out that at natural ageing the increase of maintaining time over 5 – 6 days, didn’t influence the hardness, which become constant.

The artificial ageing achieved at different temperatures and different maintaining times show:

- The maximum hardness (120 HB) was achieved at 200 °C, this value couldn’t be achieved over a maintaining time of 6 hours for 120 °C and 150 °C.
- The maintaining time for artificial ageing at optimal temperature 200°C, mustn’t prolonge over 3 hours, because the hardness decreases.

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