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Contribution to Assessment of Structural Hardening of the Solid Solutions of AS7G06.Alloy

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Abstract: In this research we studied the influence of the heat treatments of structural hardening on the evolution of the mechanical and structural properties of AS7G06 alloy gracefully provided by the foundry division of Rouïba (located in the center of Algeria) the aim of this work is to study the aptitude to hardening of AS7G06 alloy. Therefore, we carried out the application of a variety of heat treatment cycles. The result which we search is to determine the of the structural treatment parameters which offer to our alloy the highest hardening level and the adequate structure. The various experimental tests and the results obtained, on the studied alloy show an acceptable increase in the properties; therefore, the structural hardening enabled us to reach our objective; and that is confirmed by the various techniques of investigation previously described.

Key words: Structural hardening, AS7G06, Alloy

INTRODUCTION

All methods intended to improve the metals resistance; hardening by precipitation had more success[1], for a very ductile metal, such as aluminum or copper.

Hardening by precipitation[2] allows reaching high resistances while preserving a satisfactory ductility. The technique is founded on the fact that some soluble phases at high temperature can by appropriated precipitation methods, quenching and tempering; be partially or completely eliminated in the form of a hardening dispersion at temperatures close to the ambient temperature.

The hardening by precipitation has the most significant technique to increase the alloys resistance, not only of those which are intended to work at ordinary temperatures, but also of those which are used under temperatures of 1000°C and even more.

The applications of structural hardening in light alloys are extremely numerous and significant, they cover a vast industrial field.

The recent progresses made in the instrumentation allow nowadays to approach experimentally the study of this phenomenon at that atomic level and to deduce from it the causes at this scale.

Hardening is due to the interactions between dislocations and the metastable particles precipitating after setting in solution then hardening and ageing or tempering at moderate temperature (150°C).

The assessment of the interaction dislocations/ precipitates requires a good knowledge of the particles structure: composition, crystallography, degree of coherence and the geometry of the interaction with dislocations s well.

The industrial alloys, Al-Si-Mg can undergo a treatment of hardening precipitation which improves notably the mechanical properties. Although several works were devoted to the phenomena of precipitation in these alloys in various temperature ranges, several questions remain still posed and mainly relating to the kinetics, the mechanism and the sequence of precipitation as well as the shape of the precipitated particles. In our work, we repose to study the aptitude structural hardening of the aluminium solid solutions with 7% of silicon (AS7G06).

MATERIALS AND METHODS

AS7G06 alloys, are at the base of a significant groups of industrial alloys and they are the most used with heat treatment which does not require modification and where this heat treatment is limited to an extended tempering and can thus be considered as equivalent to the American products (A356), satisfying then a big market; the optimal characteristics obtained by treatments of structures modifications[3].

AS7G06 alloys have indeed showed high mechanical characteristics; therefore they let us lean on the problems posed in order to determine the optimum conditions of use of these alloys by studying in particular.

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The structural state before treatment, after setting in solution and tempering; the effect of treatment on the mechanical properties of HB hardness, the tensile strength (Rm), the lengthening (A %). A study of X- rays diffraction in order to determine the existing elements in the alloys.

AS7G06 alloy

Its chemical composition:

Fe (%)	Si (%)	Cu (%)	Zn (%)	Mg (%)	Mn (%)	Ni (%)	Pb (%)	Sn (%)	Ti (%)
≤ 0,45	6,5-7,5	≤ 0,1	≤ 0,1	0,20-0,40	≤ 0,5	≤ 0,05	≤0,05	≤0,05	0,10-0,20

Its mechanical properties:

Hardness	65,5daN/mm2
Tensile strength	20,54 daN/mm2
Lengthening	60%
Microhardness	92,37 Hv

Mould used: The mould used is out of sand where its composition is: 96% of SiO_2, of 4% of sodium silicate and the blowing by CO_2

Equipment:

A-furnaces:

Smelter: A furnace with gas with two burners was used equipped with gas aspiration. Its capacity is approximately 350 Kg lighting is semi-automatic. It is WAYNE, model 105 E-475 Al, equipped with a crucible.

Maintenance furnace (with heating resistance): For the conservation of melted metal after cast, a furnace of approximately 200 Kg capacity was used. Its temperature work is 1200°C; the temperature to which the casting was carried out varies between 680-700°C.

Furnace of the heat treatments: The thermal treatment furnace is of a great importance; therefore the choice of the furnace must be determined in a judicious way because it affects directly the final characteristics of the product. The test-tubes have then undergone the necessary treatments in a furnace of the thermal treatment; single-phase of 4100 watts power, which works under a tension of 240 volts and a current 17 amps.

B-Test of the mechanical characteristics:

Hardness: Hardness measurements are of a great utility because of their simplicity and their no destructive nature. Hardness characterizes the resistance to deformation. However, the operational process must be very precise to ensure the reproducibility and the results fidelity. It is a characteristic related in a not very precise way to the elastic limit, it enables us to recognize heterogeneities related to the anisotropies of textures and to the particles

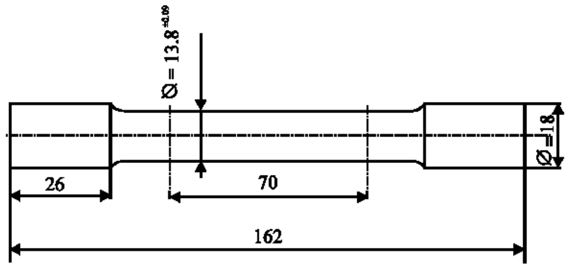

Fig. 1: Tensile specimens[4]

enlargement. The test consists in inserting a indenter in the metal to be tested, the load is constant and the dimension of the crack, which is as the larger as the metal is soft, is measured[5].

The test-tubes which undergo the thermics treatment were followed by hardness measurements by the Brinell test (HB), with a ball of 10 mms in diameter. A load of 100 KN was applied.

Test tensile: The test-tubes undergo measurements of traction after heat treatments using a tensile testing machine. This test consists of putting a test-tube Fig. 1 under a tensile effort until the rupture in order to determine the tensile strength. The value of the tensile force is showed on the screen of the machine Baldwin. The screen is graduated in N and according to the Rm relation:

$$Rm = F\ S$$

Where Rm tensile strength, F: force showed on the screen of the machine, S: section of the test-tube,

We can thus determine the tensile strength under a load of 120 KN[4] was applied.

Test of microhardness: The hardness of a material characterizes its resistance to deformation. The measurement of the microhardness is based on the determination of crack dimensions produced in material by depression of a penitrator, under the action of an applied[6].

Measurements of microhardness were taken on a microdurometer computer-assisted of (Zwick.I; ZHV10) Type Fig. 2, of Vickers penitrator, with a measuring load of 200 g, an average of six (06) measurements were carried out during each test, the enlargement used is of 200 x.

Measures particle sizes: An estimate of dendrites dimensions of a sample is relatively long: neat polishing, sometimes delicate interpretation. The precision obtained depends on the homogeneity of the sample and the number of measurements taken[7].

Fig. 2: Method of measurement of the microhardness

Fig. 3: Method of the measurement of the particle sizes[8]

For more precision concerning the structure the particles sizes were measured, with an average of seven (07) measurements for each sample Fig. 3. The particle size is calculated by the ratio:

$$Id = AB/N$$

Where:

AB: is the number of division of the rule which is equal to 100 μm.

N: it is the number of intersections of the rule with the particles.

Heat treatments applied: Test have been carried in the national company of the industrial vehicles (SNVI; ROUIBA).

In the first stage tests were carried out with thermal cycles which consists of setting on solution (homogenisation) followed by hardening (water, oil).

The first stage which is the setting in solution was carried out at different times of maintenance; in our case various times of maintenance 8 and 10 h were chosen with a maintenance temperature of 540°C; which are the necessary temperature for the maximum dissolution of the alloy elements (Si, Mg).

After the setting in solution, were dropped test-tubes in two mediums, namely: water and oil according to conditions of setting in solution.

INTERPRETATIONS

Mechanical characteristic: The mechanical properties measured on AS7G06 alloy are indicated in Fig. 4-7 considerable differences can be observed between the rough state of cast and the various treated states of examined alloy from the mechanical point of view:

Thus we can note that it has an improvement of the mechanical properties compared to that of rough of cast passing by the hardness property of 65 to 129 HB, the tensile strength (Rm) 20 to 40 daN, the microhardness 80 to 168 Hv and the lengthening from 0.6 to 79%.

Quenching in water: The setting in solution at 540°C during 8 h of maintenance followed by a of a quenching in water and a tempering, It can be noted that there is a decrease of the mechanical properties while increasing temperature (140°C-170°C-200°C) with the same time of maintenance (6-9-12 h).

Quenching in oil: The setting in solution at 540°C (8 ÷ 10 h), oil hardening, followed by a tempering we note that comparing the processing time of setting in solution of 10 h and that of 8 h and with the same environment of hardening (oil) and the same conditions of tempering, we observe that with a time of maintenance of 10 h, the hardness HB, the tensile strength Rm and the microhardness Hv; are higher compared to that of 8 h, while A% lengthening for the time of maintenance 8 h is higher than that of 10 h.

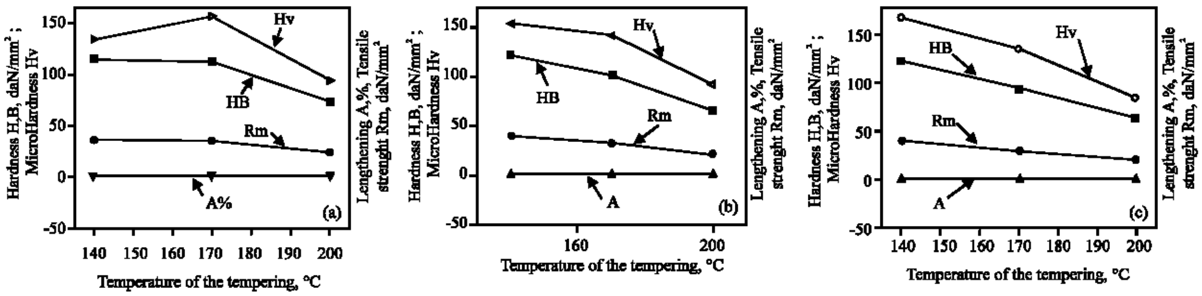

Fig. 4: Variation mechanical properties according to the time of maintenance: a) 6 h, b) 9 h, c) 12 h and the temperature of the tempering after setting in solution at 540°C for 8 h quenchined in water of the AS7G06 alloy

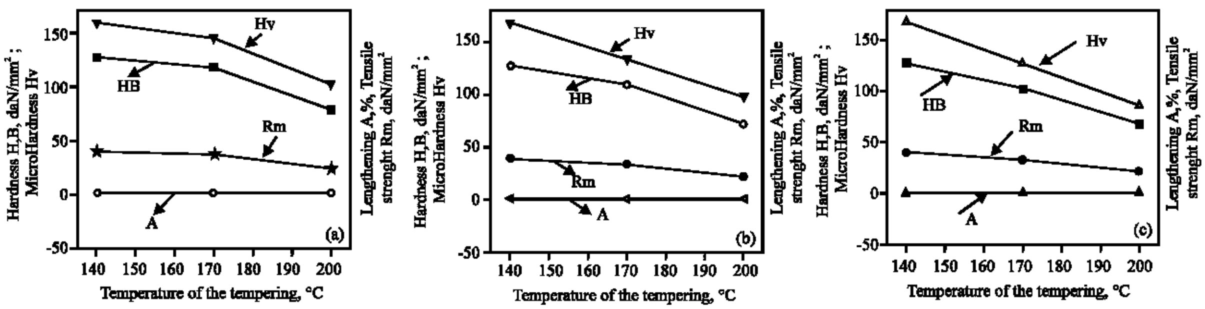

Fig. 5: Variation mechanical properties according to the time of maintenance: a) 6 h, b) 9 h, c) 12 h and the temperature of the tempering after setting in solution at 540°C for 10 h quenchined in water of the AS7G06 alloy

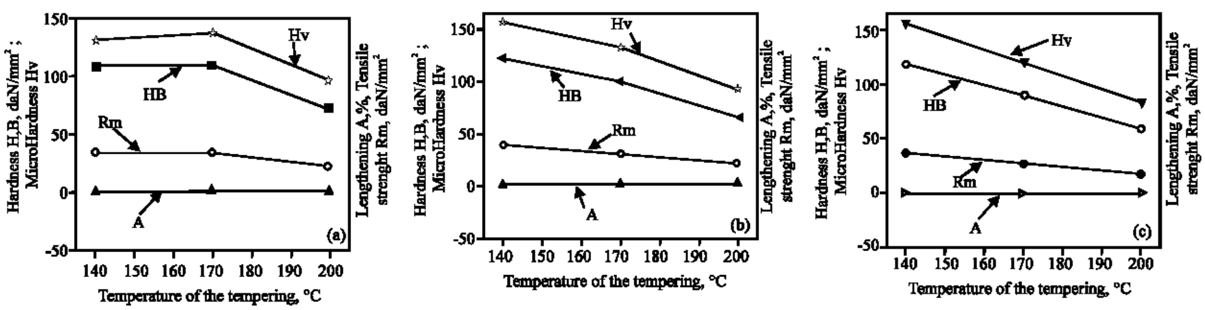

Fig. 6 Variation mechanical properties according to the time of maintenance: a) 6 h, b) 9 h, c) 12 h and the temperature of the tempering after setting in solution at 540°C for 8 h quenchined in oil of the AS7G06 alloy

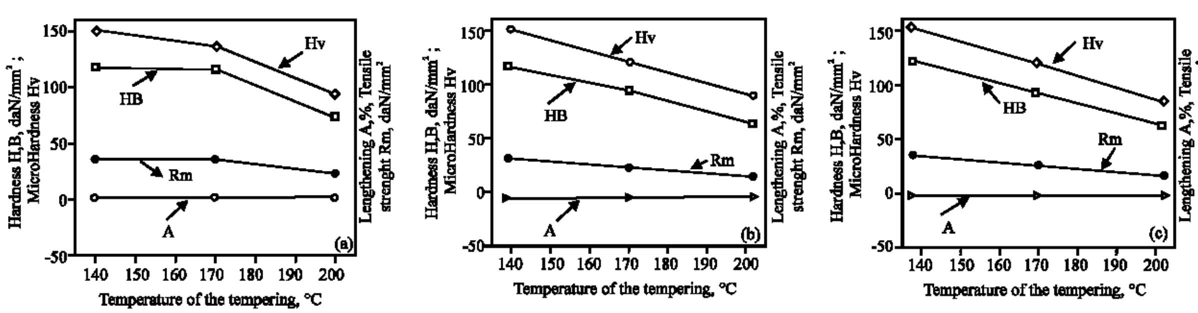

Fig. 7: Variation mechanical properties according to the time of maintenance: a) 6 h, b) 9 h, c) 12 h and the temperature of the tempering after setting in solution at 540°C for 10 h quenchined in oil of the AS7G06 alloy

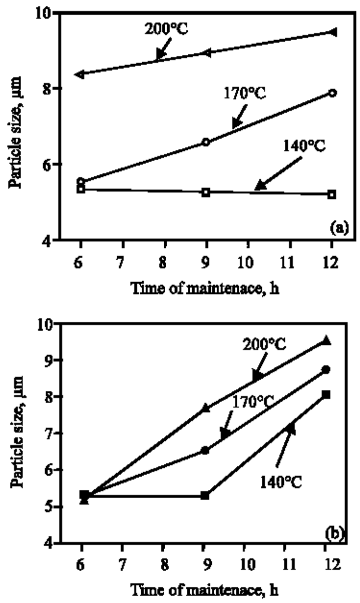

Fig. 8: Variation of particle according to the time of maintenance, the temperature sizes of the tempering after setting in solution 540°C for 8 h: a) 8 h, b) 10 h and quenchinded in water of AS7G06 alloy

Effect environment of the quenching: By comparing the quenching environment in water and that in oil (same conditions of setting in solution: temperature and time and the same conditions of tempering, the mechanical properties of hardness HB, tensile strength Rm and the Hv microhardness, for the test-tubes dropped in water are higher compared to those dropped in oil, while increasing the time of setting in solution, whereas A% lengthening for the medium of hardening (oil) is higher than that of water even if the time of setting in solution is increased. According to the studies carried out[9,10]; for the temperature of tempering of 140°C, the properties (HB, Rm) reach the maximum in the interval of time of maintenance of (9 to 12 h), these properties are almost constant and decrease beyond the time of maintenance of the tempering of 12 h.

It results that the properties obtained for a temperature of tempering of 200°C; are weak compared to those obtained at a temperature of tempering of 140°C and for a time of maintenance of 12 h. That is explained by the premature increase in the size of the precipitates of Mg_2 Si which reaches its maximum size before a time of maintenance of 6 h in the case of the tempering with 200°C. But for a temperature of tempering of 140°C the maximum size of the precipitates is reached only after a time of maintenance of the tempering of 9 h. The increase beyond the maximum value, causes the decoherence of the precipitates of Mg_2 Si of aluminium mould and consequently a reduction in the final mechanical characteristics of AS7G06 alloy.

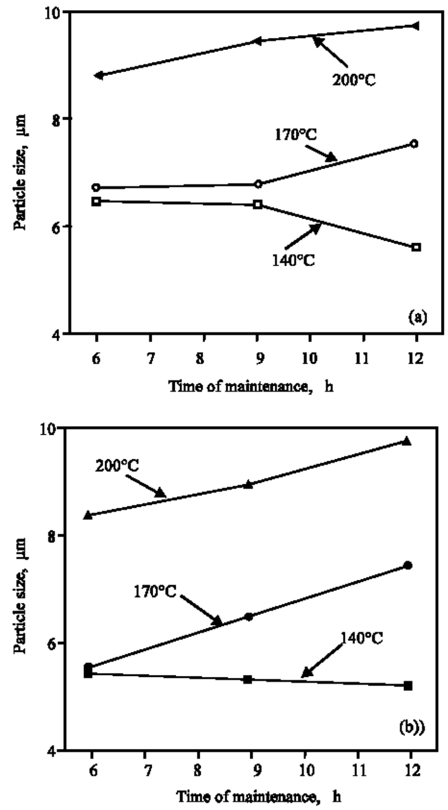

Fig. 9: Variation of particle according to the time of maintenance, the temperature sizes of the tempering after setting in solution 540°C for a) 8 h; b) 10 h and quenchinded in oil of AS7G06 alloy

Particle sizes: According to the measurement of the particle sizes and according to the calculation of the average of the particles sizes indicated in the tables for each sample (Fig. 8-9) we one can say that:

The distance between dendrites of silicon decreases when the time of maintenance of setting in solution is increased, for instance; for a setting in solution of 10 h the distance between dendrites of silicon is compared to that with a time of maintenance of 8 h.

The distance between dendrites of silicon decreases much more when we passes to the tempering with lower temperatures and longer times, it is the case for instance of tempering at a temperature of 140°C during a time of maintenance of 12 h. On the other hand in the case of tempering at higher temperatures and with shorter times of maintenance, there is an increase in the interdendritic distance it is the case for example of a tempering at 200°C during a time of 6 h.

CONCLUSION

The parameters of setting in solution (homogenisation) such as time and temperature do not have a great influence on the mechanical and structural characteristics of alloy. Thus the treatment of setting in solution is only to homogenize the chemical composition of alloy. The temperature of setting in solution is a parameter at summer chooses judiciously because its rise beyond the maximum causes burns with the joints of the grains and consequently deteriorates the final properties. The time of maintenance of setting in solution, influences the characteristics slightly; it makes increase the properties of hardness, tensile strength and the microhardness and decrease lengthening thus on the other hand. The hardening, which is the operation succeeding the setting in solution (homogenisation), acts distinctively on the choice of the environment of hardening, because hardening in water; give characteristics mechanical and structural final better than in the case of oil hardening, the tempering is a very important treatment because all the processes of artificial ageing proceed in this phase is by varying the temperature or the time of maintenance of tempering. The temperature of tempering influences directly the characteristics of alloy then the increase exaggerated in the temperature of tempering deteriorates these characteristics. Then, it is preferably to choose the lowest temperature of tempering for our alloy (140°C). The time of maintenance of the tempering influences in an ascending way the final characteristics for a temperature of 140°C, the increase in the time of maintenance of tempering causes the increase in the characteristics, but in the case of 170 and 200°C the increase in the time of maintenance of tempering acts in the contrary direction. That causes the increase in the size of the precipitates and consequently generates the decoherence of the precipitates of Mg_2Si of the aluminium matrix. The influence of the heat treatments of age hardening (put in solution, hardening, tempering) on the structure is not very important bus in the case of aluminium and its alloys, it there with step of phase shift. The parameters of the heat treatments of age hardening play on the reorganization, the redistribution of the silicon crystals and the precipitates of Mg_2Si which in result determines the size and dimensions of the structural components.

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