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The influence of work parameters about the heat treatment applied to AlCu4Mg1,5Mn - aluminum alloy

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Abstract

The paper presents some heat treatments technologies applied to aluminum alloys to improve technological parameters. The experimental tests were accomplished for the deformabile AlCu4Mg1,5Mn aluminum alloy, with hardening temperatures between (500 – 530)°C and artificial ageing. The artificial ageing is made in magnetic and vibrator field. The efficient of same heat treatments depends on a series of factors, some depending on the material and otheres of the work parameters. The optimum variant or variants can be obtained by correct joining of the chemical composition with the values parameters of heat treatments and supplementary some utilization factors of stimulating the process at the crystalline net level.

Key words: Aluminum alloy, magnetic field, vibrations, heat treatment.

1. Introduction

Aluminum alloys such as Al-Cu, Al-Mg, Al-Cu-Mg and also duralumin type alloys, although in a lesser extent may be subjected to final hardening and aging heat treatmentin order to improve mechanical characteristics.

In addition to the classical heat treatment, mentioned above, in order to obtain higher values of the properties there are applied some unconventional methods. These include treatments in electromagnetic fields and treatments in the vibrator field.

2. Experimental researches

2.1. Materials

To highlight the influence of these fields and the heating temperature for hardening, was studied the AlCu4Mg1,5Mn alloy, with chemical composition presented in table 1.

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Table 1. Chemical composition

Alloy	Cu	Mn	Mg	Cr	Ti	Si	Fe	Al
	Chemical composition, in [%]							
AlCu4Mg1,5Mn	4,02	0,541	1,28	0,027	0,0025	0,267	0,481	Rest

2.2. *Heat treatments applied*

The samples from this material ware subjected to the heat treatment consisting of hardening (with cooling in water) at different temperatures, and after this was applied for each temperature the aging in several variants.

The samples which were hardened in water were heated and maintained at 170° C for one hour with overlapping the alternative and stationary electromagnetic field. The electromagnet input was done at AC and industrial frequency of 50Hz. Brinell hardness values obtained after the application of heat treatments, are shown in table 2.

Table 2. Brinell hardness obtained after heat treatments

Type of heat treatment	**Alloy**	**HB Hardness after hardening and ageing**			
		Hardening temperature [°C]			
		500	**510**	**520**	**530**
Hardening + natural ageing (at 20°C, 7 day)	AlCu4Mg1,5Mn	117	119	98	106
		Ageing temperature and duration			
		170°C/1h	**170°C/1h**	**170°C/1h**	**170°C/1h**
Hardening + regular artificial ageing	AlCu4Mg1,5Mn	110	119	110	102
Hardening + artificial ageing in stationary electromagnetic field		112	129	114	105
Hardening + artificial ageing in alternative electromagnetic field		126	128	110	106

In the case of vibrator field, the additional energy from the thermic field which is overlapped to the artificial aging from the artificial aging is represented by the mechanical vibration. They are submitted to the warm environment, liquid (oil), in which the pieces are maintained to aging, with an elastic segment excited by an electromagnet. In experimental attempts were used mechanical vibrations at frequencies of 50 and 200 Hz, the proper heat treatment consisting of: hardening from 510°C in water and followed by artificial hardening at 170°C, one hour with the application of vibrations.

Same treatments were applied to the strech and resilience samples. The obtaining results are shown in tables: 3...7.

Table 3

Alloy	**Artificial ageing at 170°C in DC for one hour**											
	Hardening temperature											
	500°C			**510°C**			**520°C**			**530°C**		
$AlCu_4Mg_{1,5}$ Mn	σ[N/m^2]	δ[%]	ψ[%]	σ[N/m^2]	δ[%]	ψ[%]	σ[N/m^2]	δ[%]	ψ[%]	σ[N/m^2]	δ[%]	ψ[%]
	5,2·10^8	3,5	-	3,12·10^8	17,5	14,4	2,65·10^8	7,5	4,9	2,2·10^8	3,5	4,9

Table 4

Alloy	**Artificial ageing at 170°C in DC for one hour**		
	Hardening temperature		
	500°C	**510°C**	**520°C**
AlCu$_4$Mg$_{1,5}$Mn	KCU[J/m^2]	KCU[J/m^2]	KCU[J/m^2]
	8,4	8,6	7,9

Table 5

Alloy	**Artificial ageing at 170°C in AC/1h**		
	Hardening temperature		
	500°C	**510°C**	**520°C**
	KCU [J/m^2]	**KCU [J/m^2]**	**KCU [J/m^2]**
AlCu$_4$Mg$_{1,5}$Mn	6,1	5,2	5,25

Table 6

Alloy	**Hardening and artificial ageing at 170°C in AC for one hour**								
	Hardening temperature								
	500°C			**510°C**			**520°C**		
	σ_r[N/m^2]	δ[%]	ψ[%]	σ_r[N/m^2]	δ[%]	ψ[%]	σ_r[N/m^2]	δ[%]	ψ[%]
AlCu$_4$Mg$_{1,5}$Mn	$3,55\cdot10^8$	6,3	6,6	$3,05\cdot10^8$	8,5	4,9	$3,3\cdot10^8$	8,5	4,9

Table 7

Alloy	**Hardening from 510°C and artificial ageing at 170°C, with using the vibrations**					
	Hardening in water+ageing at 170°C; 50Hz			**Hardening in water+ageing at 170°C;200Hz**		
	σ_r[N/m^2]	**δ[%]**	**ψ[%]**	**σ_r[N/m^2]**	**δ[%]**	**ψ[%]**
AlCu$_4$Mg$_{1,5}$Mn	$5\cdot10^8$	18,2	19	$4,67\cdot10^8$	18,4	21,2

2.3. Obtained structures

In figures 1...6 are presented the metallographic structures which are obtained after the analysed specific heat treatments.

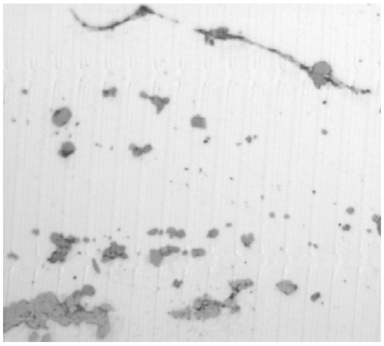

Figure 1. $AlCu_4Mg_{1,5}Mn$ alloy after hardening in water from 510°C and natural ageing. Attack: 10% H_3PO_4. (1000:1)

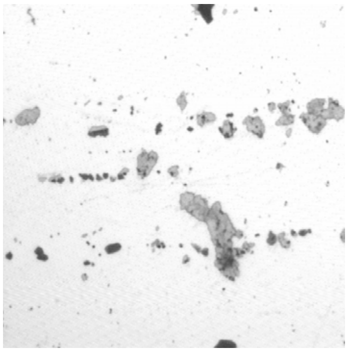

Figure 2. $AlCu_4Mg_{1,5}Mn$ alloy after hardening in water from 510°C and artificial ageing at 170°C, 1h. Attack: 10% H_3PO_4. (1000:1)

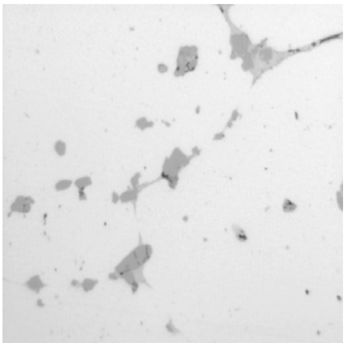

Figure 3. $AlCu_4Mg_{1,5}Mn$ alloy after hardening in water from 510°C and artificial ageing at 170°C, 1h in stationary electromagnetic field. Attack: 10% H_3PO_4. (1000:1)

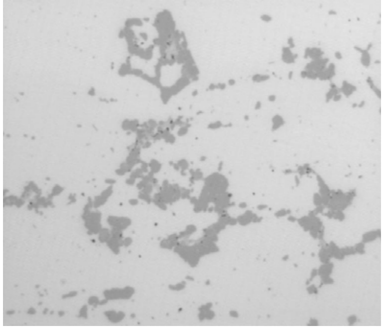

Figure 4. $AlCu_4Mg_{1,5}Mn$ alloy after hardening in water from 510°C and artificial ageing at 170°C, 1h in alternative electromagnetic field Attack: 10% H_3PO_4. (1000:1)

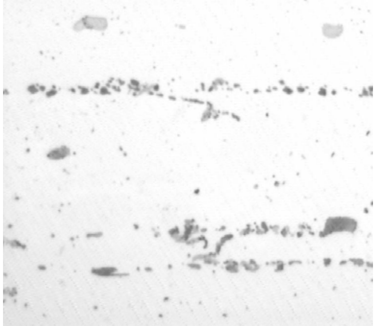

Figure 5. $AlCu_4Mg_{1,5}Mn$ alloy after hardening from 510°C in water and artificial ageing at 170°C, 1h in 50Hz vibrator field. Attack: 10% H_3PO_4. (1000:1)

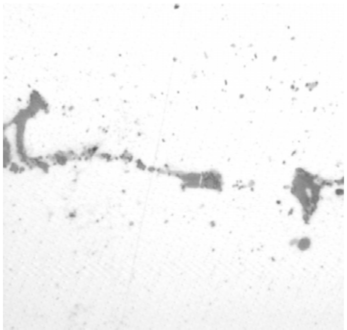

Figure 6. $AlCu_4Mg_{1,5}Mn$ alloy after hardening from 510°C in water and artificial ageing at 170°C, 1h in 200Hz vibrator field. Attack: 10% H_3PO_4. (1000:1)

The delivery alloy structure consists of a mass of α solid solution and darker inclusions of precipitated phases as: Al_2Cu, Al_2CuMg, Al_3Mg_2, Al_6Mn, Al_6Mg_4 and others. Among these, for the heat treatments are important the soluble compounds, such as Al_2Cu, Al_2CuMg, Al_6Mg_4.

During the heating and maintaining for hardening, these phases decompose, the components diffused in the solid solution and by the quick cooling they do not separate anymore; as a result, after hardening, the amount of precipitated phase's decreases, which is sometimes observed in the metallographic structure.

During the natural and artificial ageing, the tendency of precipitation of such compounds exists, but the process is not completed, resulting only the GP zones, namely the coherent θ^{I} and θ^{II} phases. These phases are not seen at the metallographic optical microscope, only at the roentgen structure analysis.

By applying some external energy fields, can be influenced the kinetics of the formation of GP areas (which was followed in this paper) and also some dispersion of insoluble phases, namely finishing the solid α solution crystals.

3. Conclusions

From the studies and experiments made in this paper, it can be highlighted the following conclusions:
- The heating temperature for hardening has a decisive influence on the heat treatment results; The optimum temperature for the studied alloys is 510°C, with similar results, can also be accepted the 500°C one, but of course, the maintenance duration has to be longer;
- The application of these electromagnetic fields and vibrator over the thermic one at the artificial ageing increases the performances of heat treatment, obtained results far exceeding the results from the natural ageing; The alternative electromagnetic field gives better results than the stationary one.
- High hardness obtained are also due to the large amounts of copper and magnesium in composition, which gives rise to the soluble phase, which facilitates the hardening;
- Overlapping the supplimentary energetic fields over the thermic ones from the artificial ageing, has more beneficial effects on the hardening process; we consider that the additional energy from the crystalline grid contribute to stimulation of diffusion processes, which cause the cold hardening for the crystalline grid by the formation of Guinier – Preston areas and / or θ^{II} and θ^{I} phases;
- Exceeding the optimal heating temperature for hardening compromises the results in all variants.

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