INFLUENCE OF Cu AND Ti IN THE MECHANICAL STRENGTH OF THE Al-Si5% Cu1% Mg ALLOYS

JOSÉ COSTA DE MACÊDO NETO[1*], ANDRÉ OSAMU CARNEIRO NABESHIMA[2], SOLENISE PINTO RODRIGUES KIMURA[3], MELISSA GURGEL ADEODATO VIEIRA[5], JOÃO EVANGELISTA NETO[4]

[1*] Dr. Professor em Engenharia de Materiais, UEA-EST, Manaus-AM. Fone: (92) 3878-4326, jotacostaneto@gmail.com
[2] Especialista em Processos de Fabricação Mecânica, UEA-EST, Manaus-AM. Fone: (92) 3878-4326, aosamu0167@gmail.com
[3] Drª. Professora em Engenharia de Materiais, UEA-EST, Manaus-AM. Fone: (92) 3878-4326, solenisekimura@yahoo.com.br
[4] Dr. Professor em Engenharia de Materiais, UEA-EST, Manaus-AM. Fone: (92) 3878-4326, joao_evangelista_neto@gmail.com
[5] Drª. Professora em Engenharia Química, Departamento de Desenvolvimento de Processos e Produtos, UNICAMP-FEQ, São Paulo-SP, Fone: (19) 35210358

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ABSTRACT: The objective of this study was evaluate the mechanical properties of the alloy Al-Si-5%Cu-1%Mg adding deferential amounts of copper and titanium. To evaluate the mechanical properties was carried out hardness tests and tensile test. For microstructural evaluation used the scanning electron microscopy. For the tests league H4 got better mechanical properties.
KEYWORDS: Aluminum alloys, Cu and Ti, mechanical strength.

INTRODUCTION

Although aluminum has a lot of versatility due to its versatility used in fusion processes, there is still a big gap in relation to obtaining mechanical properties and microstructure control. Thus, research has developed technologies, such as deformation by conducting friction process, and the use of nucleating elements in the liquid metal. Yet, so far, no process has proved more effective and economical than the inclusion of alloying elements in order to modify the mechanical properties and microstructure (Zhang et al., 2014)

The objective of this work is to study the influence of adding varying amounts of copper alloying elements (Cu) and titanium (Ti) on the microstructure and mechanical properties of aluminum alloy Al-Si5% Cu1% Mg.

MATERIALS AND METHODS

Preparation of alloys, casting and heat treatment

In this work we were prepared 4 different aluminum alloys. All samples were molded under high pressure injection. The injection parameters were the same for all alloys. To carry out this study four chemical compositions of aluminum alloy-based alloy AC 4D were used, standardized in JIS H 5202, where changes were made in the chemical elements Cu and Ti. The Table 1 shows the nominal chemical composition from the norm JIS H 5202.

Table 1. Nominal chemical composition of the alloy AC 4 D from the norm JIS H 520

Symbol		Si	Cu	Fe	Mg	Zn	Mn	Ti	Cr	Pb
AC 4 D	A1-Si5Cu1Mg	4,5-5,0	1-1,5	0,6	0,4-0,6	Máx. 0,55	Má. 0,50	Máx. 0,20	-	Máx. 0,1

After obtaining the already solidified alloys, we analyzed their chemical compositions shown as H1, H2, H3 and H4 (Table 2). For this analysis it was used an optical emission spectrometer from Shimadzu, Model OES 5500. In alloy H2 it was increased the amount of Cu and Ti in relation to H1 (base alloy). In alloy H3, Cu was increased and Ti was also increased compared to H1. The alloy H4 was increasing Cu and increased Ti relative to H1.

Table 2. Chemical composition of alloys studied showing variations in Cu and Ti.

ALLOY	Al	Si	Cu	Fe	Mg	Zn	Mn	Ti	Cr	Pb
H1	92,027	5,495	1,220	0,499	0,447	0,039	0,144	0,103	0,003	0,005
H2	92,302	5,244	1,202	0,468	0,456	0,028	0,102	0,162	0,003	0,004
H3	91,968	5,286	1,497	0,478	0,521	0,019	0,059	0,132	0,003	0,001
H4	91,739	5,500	1,466	0,438	0,550	0,024	0,078	0,165	0,003	0,003

After alloys production, they were heat treatmently treated by (T6-precipitation and aging) treatment. Table 3 shows the heat treatment parameters used in the alloys.

Table 3. Parameters of fusion process and heat treatment.

Parameters	Temperature (°C)	Time (h)	Time (min.)
Melting temperature	730		
Solubilization treatment temperature	505	2	15
Cooling	60		2
Aging treatment temperature	147	2	20

After heat treatment were taken specimens of the piece injected and treated for carrying out the hardness test, tensile, and scanning electron microscopy.

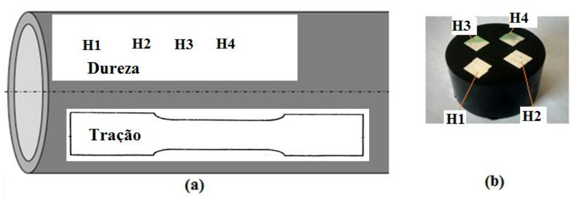
Microstructural Analysis

For this analysis were used a Scanning Electron Microscope (SEM) brand JEOL model JSM 5610 with 200X and 1000X increases.

Hardness test

The hardness assay was performed in an equipment of the brand Instron model Wilson Rockwell 2000 series, in HRB scale (Hardness Rockwell B) following the norm JIS Z 2245. In each injected alloy were taken a sample. Samples were embedded, sanded and polished. Then 10 hardness measurements were made on each sample. Samples were taken of the alloys injected in the form of a hollow tube. Figure 1 shows the part of the region injected where the samples were taken.

Figure 1. (a) Part of the piece where the samples were taken for hardness and traction testing. (b) Samples embedded for the hardness and SEM assay.



Tensile test

The tensile test was performed according to JIS Z 2241: 2011 with specimens taken from the piece itself (Figure 1). The test was conducted on a universal testing machine brand EMIC, model DL 2000 with a 2000kgf load cell, extensometer with 25mm of L_0 and the speed of testing was 5mm/min. Obtaining the elongation values was obtained directly in the software. This test was replicated 10 times and was then extracted from the averages of the data obtained.

RESULTS AND DISCUSSION

Hardness

Table 4 shows the results of the hardness test. The values for all alloys are very close. However, the hardness values for alloys H1, H3 and H4 are larger than the alloy H2. This was due to increased amount of Cu in these alloys compared to Ti. The Cu tends to form intermetallic increasing the hardness in alloys H3 and H4 (CHANG *et al.*, 2009). Titanium has the effect of refining the grain of aluminum alloys increasing the resistance (MACHADO, 2012). Therefore, there was a combined effect of grain refining and intermetallic appearance that increased hardness of alloys H3 and H4 in relation to the other alloys.

Table 2. Hardness average after thermic treatment of the studied samples

Alloy	**Points of measures**				**Final Avarage ± S. D.**
	P1	**P2**	**P3**	**P4**	
H1	53,9	53,6	52,7	52,6	53,20 ± 2,39
H2	50,8	51,3	4937	50,3	50,53 ± 1,87
H3	52,6	51,7	52,5	52,9	52,43 ± 1,88
H4	53,6	53	53,1	52,9	53,15 ± 1,73

S.D.: Standard Deviation

Tensile test

Table 3 shows the results of the tests. Considering the upper limit of the standard deviation, the alloy H4 had a higher yield stress and rupture compared to the other alloys. The alloys H1, H2 and H3 obtained values for the yield stress and rupture too close, also considering the upper limit of the standard deviation. This behavior to the alloy H4 (with higher amount of Cu) suggests that there was the formation of GP zones in the initial phase of aging as the formation of precipitates, which increased the mechanical strength (ZEREN *et al.*, 2001). The elongation was also higher for the alloy H4 suggesting that there was a greater influence of the amount of Ti in the alloy, because this element has the function of increasing ductility (HARO-RODRÍGUEZ *et al.*, 2011).

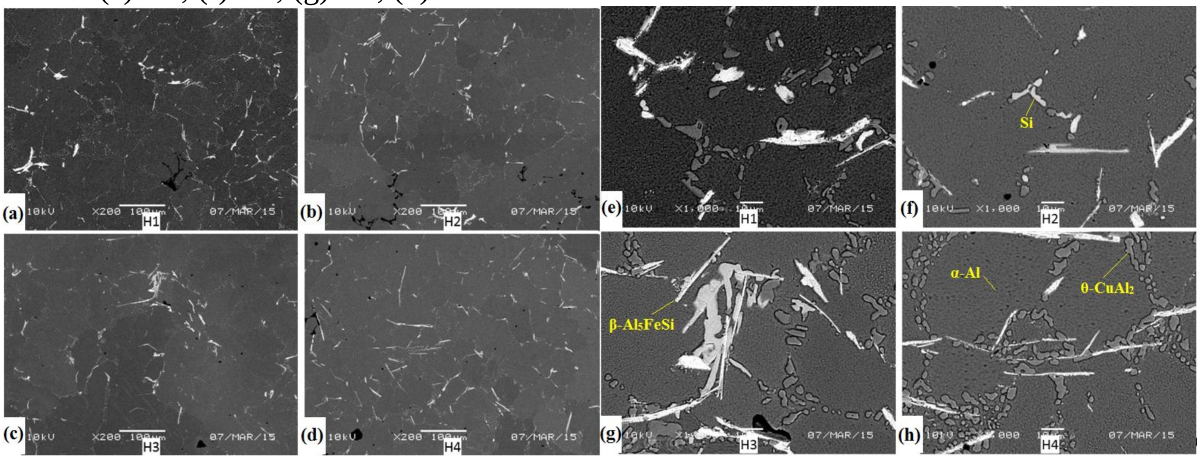
Table 3. Tensile test results.

Alloys	**Obtained data**	**Yield stress (kgf/mm^2)**	**Rupture (kgf/mm^2)**	**Elongation (%)**
H1	**Avarage ± S. D.**	18,86 ± 0,56	25,52 ± 0,81	2,19 ± 0,34
H2	**Avarage ± S. D.**	19,04 ± 0,39	25,05 ± 0,75	2,04 ± 0,30
H3	**Avarage ± S. D.**	18,43 ± 0,78	25,51 ± 0,98	2,28 ± 0,48
H4	**Avarage ± S. D.**	19,48 ± 0,95	26,36 ± 0,96	2,49 ± 0,54

Microstructure

The analysis of SEM micrographs of alloys H2 and H4, which have a higher titanium content (Figure 2b and d) show the presence of a higher nucleation, smaller grain sizes, as well as the presence of increased number of precipitates in the matrix (MACHADO, 2012). While refining, the addition of the titanium only in alloy H2 (Figure 2b) showed decreased in the hardness, while in the alloy H4 (Figure 2d) due to the addition of two elements, there was an increase in hardness. The Alloy H3 (Figure 2c), because it has low titanium content, showed bigger grains with increased dissolution of precipitates in the matrix, however due to the addition of copper there was only the maintenance of hardness (APELIAN, 2009). It was also observed by micrographs that started to happen the appearance of the phases β-Al_5FeSi, α-Al, θ-$CuAl_2$ e Si (Figure 2f, g, h) after the heat treatment (ZEREN *et al.*, 2001).

Figure 6 - Scanning Electron Microscopy (SEM), 200X: (a) H1, (b) H2, (c) H3, (d) H4. 1000X: (e) H1, (f) H2, (g) H3, (h) H4.



CONCLUSIONS

-The Hardness of the alloys H1, H3 and H4 were higher than the alloy H2. For alloys H1, H3 and H4 there was a combined effect of Cu and Ti elements, causing an increase in the refining of precipitates and refine of the dendritic grains.

-For The tensile test, results showed that, considering the upper limit of the standard deviation, the alloy H4 had a higher yield stress and rupture if you compare to the other alloys. The alloys H1, H2 and H3 obtained values for the yield stress and rupture very close, considering the upper limit of the standard deviation.

-In Study confirmed the effectiveness of titanium acting as a grain refiner, as compared H1 and H3 alloys, which lacked titanium addition, H2 and H4 alloys showed a significant reduction in the size of dendritic grains. All alloys showed the phases β-Al_5FeSi, α-Al, θ-$CuAl_2$ e Si, after the heat treatment.

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