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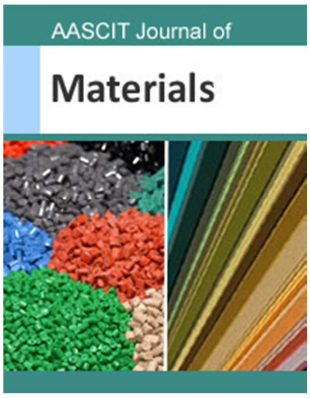

Effect of Solution Treatment in CuCrZr Alloy Structure

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Abstract

Precipitation hardening is a method used to increase strength and hardness of heat-treated alloys. In this investigation, the alloy was subjected to thermal hardening cycles to study the effect of cycling on microstructure and its consequences on properties. Results indicate that there is a single treatment time for each solution treatment temperature. These two parameters are the variables that determine the volume of precipitate hardeners available to increase hardness in each cycle. As for thermal cycles, its application does not degrade the alloy. The Copper-Chrome-Zirconium microstructure alloy resists four thermal cycles without showing any sign of loss of hardness, which indicates an unchanged microstructure to thermal cycles.

1. Introduction

Nowadays, it is common to find copper base materials with high mechanical strength and high conductivity. However, these characteristics are mutually exclusive when materials are hardened by conventional processes, such as solution hardening, deformation hardening or grain refining.

Alloy elements reduce conductivity and hardening by deformation becomes harmful by limiting resistance and decreasing thermal stability. Fortunately, age hardening copper alloys areable to overcome these defects, resulting in improved mechanical and electrical performance. The first step in this process is the solubilized heat treatment. It is used to dissolve any precipitate so as to generate a solid solution of single-phase structure.

A well-known feature of these alloys is that the greater the amount of hardening elements put into solution, the greater their potential for increased strength. However, dissolving solutes require the correct choice of temperature and treatment time. Although temperature is a parameter that arises from the equilibrium diagram, it is not so regarding time, for which there is scarce data available suggesting that the higher the treatment temperature is, the shorter the treatment time exposition will be.

The dissolution process of precipitates has been studied by several authors. Yang He et al [1] studied dissolution times of magnesium silicide precipitates belonging to the AA 6014 alloy as a function of solubilized temperature. They followed the evolution of size of precipitates from SEM images and determined that at high solubilization temperature, in this case 570°C, only 1 minute of exposure is required to achieve total solubilization of Mg_2Si phase. This result compared 30 minutes of exposure to temperatures of 530°C.

Solution treatment is also applied in stress relief. Lombardi et al [2] studied the effect of solution treatment on residual stresses generated by inserting a cylinder liner (gray iron) into a motor block (aluminium alloy AA319), which can cause cylinder distortion or fracture of the block of the engine. Results indicate that solution treatment at 470°C causes gradual relief of traction residual stresses at soaking times of 5 h where deformation is completely relieved. At 500°C, strain is relieved faster (<0.5 h). Although cooling to room temperature causes partial restoration of residual stresses, their magnitude will be much lower than that for the casting condition. R. Fernandez Gutierrez et al [3] studied the influence of solubilization time on the microstructure of three aluminum-copper alloys to observe the effect on the accumulation of damages during tensile deformation. Results indicate that, in an alloy having a microstructure formed by an aging-hardened α-Al matrix and interdendritic aluminides, solution treatment affects the interdendritic networks of aluminides differently and this effect depends on the composition of the alloy.

Effects of corrosion are also related to solution treatment. The 5000 series aluminum alloys are used as substitutes for fiber reinforced polymer (FRP) in boats. However, they suffer corrosion in the marine environment when the boat is at high speed. For this reason, Seong-Jong Kim and Seok-Ki Jang [4] studied the effect of solution treatment on corrosion of 5000 series aluminum alloys. The slow strain rate test on seawater revealed that solution treatment under optimal conditions yields improvements in elongation, time to fracture, and number of pores. Other researchers, such as A. Nikas [5] et al studied the effect of solution treatment on porosity and mechanical properties in AlSi10MnMg (Fe) alloy. They found higher values in porosity as temperature and time of solution treatment increased. The increase in temperature and time of solution treatment benefits the performance and strength of the alloy.

The objective of the study conducted by Yi-Ling Chang [6] et al was to demonstrate the effect of the heating rate on the properties of aluminum alloy A6082 during solution heat treatment. This research showed that increasing the solubility limit for silicon-magnesium it is possible to improve the response of the alloy. Ultra-rapid heating in a salt bath reduces duration of solution treatment and maintains the grain size on a smaller scale, thereby optimizing properties.

Duration of the T4 / T6 process is also reduced. The study by T. A. Costa [7] et al proposes to evaluate the role of the time of solution treatment during the T6 heat treatment of an alloy of Al-5,5% Si-3,0% Cu. Researchers found that by increasing the time of solution treatment interdendritic spacing was higher. In addition, it was found that mechanical properties improve when solubility of alloys increases with temperature. Martensitic transformation and reversibility in Copper-based shape memory alloys are also strongly influenced by the rate of quenching [8].

In the process of hardening of CuCrZr alloy, solution treatment aims to dissolve chrome and Zirconium and then make them precipitate coherently in the imperfections of the matrix. On the one hand, the Cr precipitates as a pure element and on the other, the Zr is combined and precipitatedas a compound of the Cu_xZr type [9, 10]. The purpose of this work is to study the solution treatment process of CuCrZr alloy as a function of temperature and annealing time as well as the effect of thermal cycling on microstructure.

2. Experimental

The alloy used in this work is a commercial material of the CuCrZr alloy (C18150) solubilized and aged with hardness of 81 HRB, from a company engaged in the manufacture of copper base alloys. Hardness found was detected by a BSG equipment, on the HRB scale as recommended by ASTM E 18 for copper base alloys, using a load of 100 kg and a 1/16 "ball penetrator. Table 1 shows the chemical composition values given by specification C18150 published on the website matweb.com; A measurement using an X - ray fluorescence kit (Bruker - Titan, S1) was also carried out in the laboratory to corroborate whether the material in question had the chemical composition given by the American literature. For heat treatment, resistance furnaces were used, with no controlled atmosphere.

Table 1. *Chemical composition of CuCrZr alloy (UNS:C18150).*

Alloy elements	Nominal alloy composition C18150 according to Matweb.com * [%]	Composition measured in laboratory [%]
Cr	0.5 - 1.5	1.03
Zr	0.05 - 0.25	0.14
Si	0.20 - 0.35	0.16
others		0.35
Cu	Rest (98.25 - 99.45)	Rest (98.32)

3. Results

A study of dissolution kinetics of hardening precipitates, starting from a sample with complete heat treatment of precipitation hardening, that is, solubilized and aged was carried out. Figure 1 shows that dissolution rate of solutes in the initial stages of thermal cycle (represented by the slope of the curves) increases with temperature. Increasing temperatures in each cycle of solution treatment and tempering, promotes a softening at shorter times. The result is an extremely soft solid solution, in an ideal condition for cold forming. These data show us the risk of unexpected heating in castings made of CuCrZr alloy, as a significant loss of properties occurs due to a very high dissolution rate of hardening precipitates.

Figure 1 shows that all curves have an asymptotic and convergent behavior at 30 ± 5 HRB. This behaviour indicates the total time of solution heat treatment, which must be carefully evaluated. This total time is determined where the rate of dissolution decreases, with zero trend. This value indicates the end of the dissolution of solutes for a certain temperature; if the treatment continues, other characteristics of the structure, such as grain size, will begin to degrade.

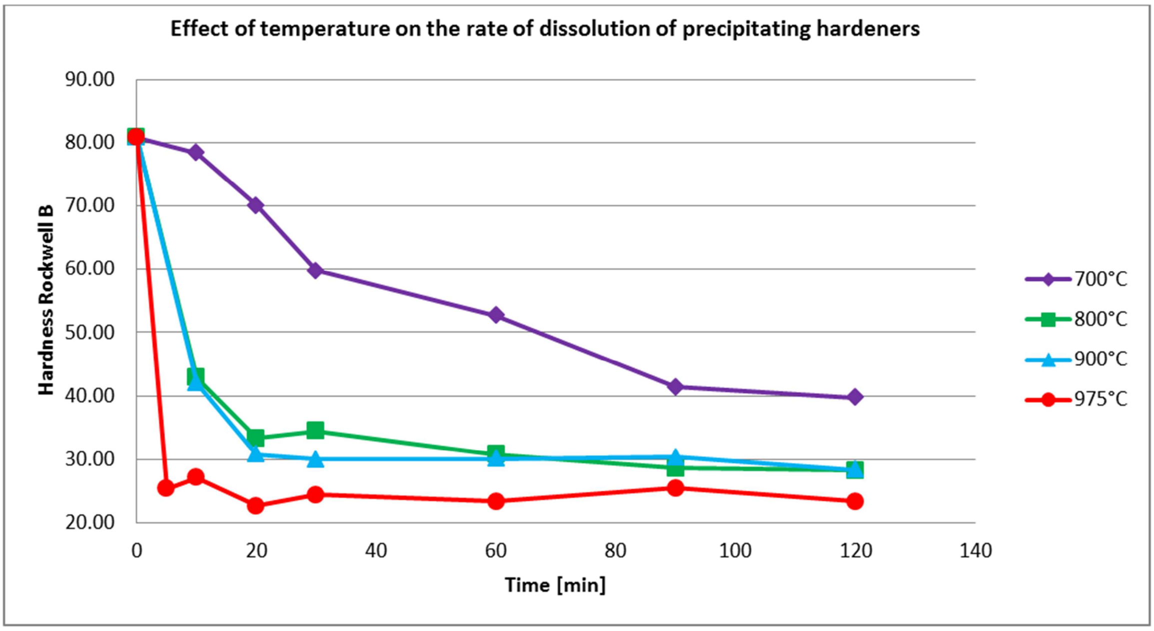

Figure 1. *Hardness values for samples subjected to solubilization cycles at different times and temperatures.*

In Figure 2, the resulting hardness values exhibited by the samples solubilized at 975°C, after a cycle aged at 500°C for 3 hours, indicate that, in both shorter and longer solubilization times, hardness does not change significantly. This suggests that the total volume of precipitated hardeners available at 5 minutes of solution treatment is constant and unique since it is observed, that continuing treatment up to 120 minutes does not produce significant changes in final hardness.

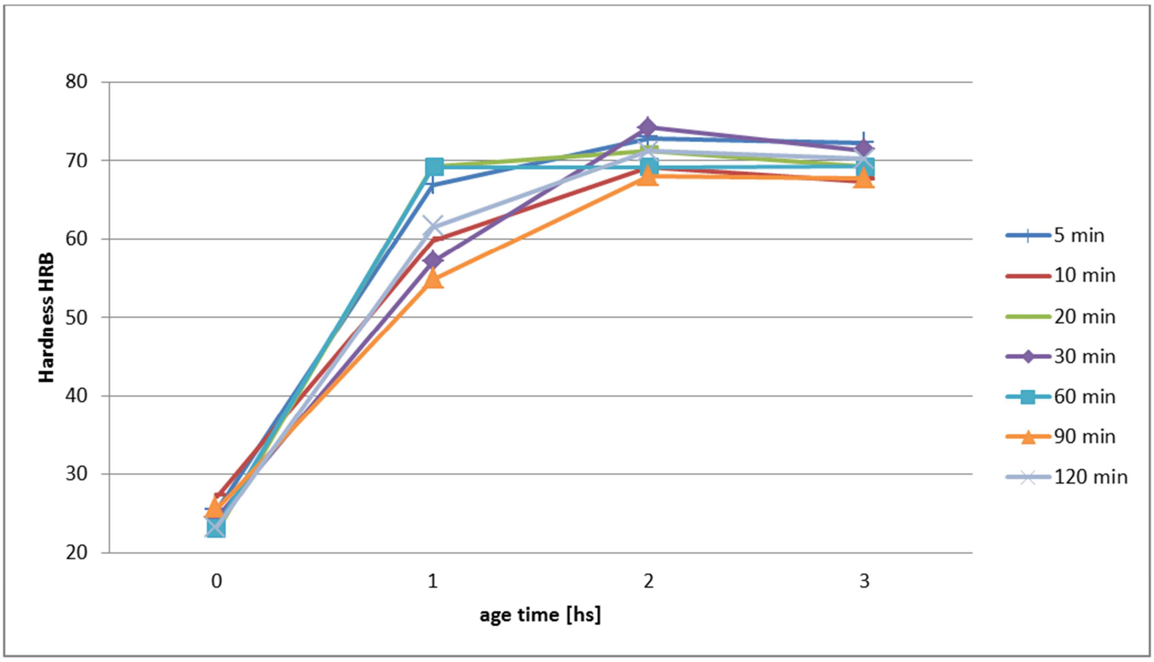

Figure 2. *Hardness values for samples solubilized at 975°C during different times and aged at 500°C in 3 consecutive cycles of 1 hour each.*

4. Use of Multiple Cycles and Their Effect on the Structure

Already solubilized and aged samples, are subjected to three thermal cycles of precipitation hardening. Trials show an increasing evolution of hardness, a fact that is evident in those solubilized at 900°C for 10 minutes (light blue in the graph of Figure 3). Results suggest that each complete cycle provides precipitates consistent with the next cycle, generated in each new solubilization and quenching cycle, for unknown reasons.

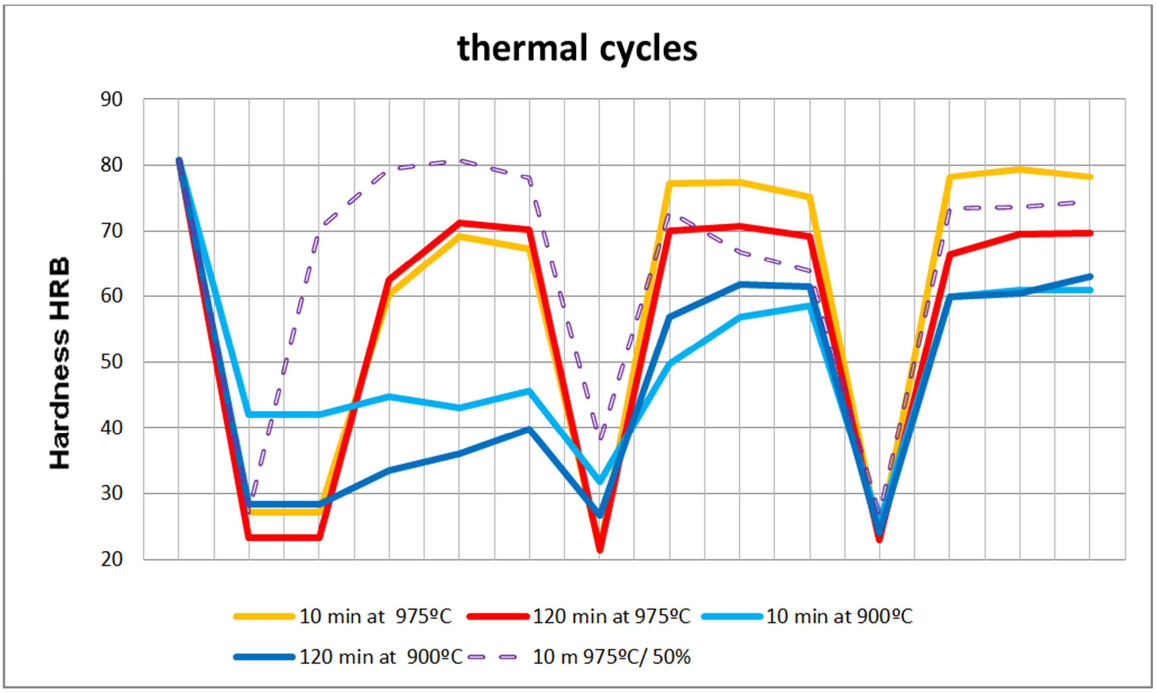

Figure 3. *Hardness values for samples that were subjected to 3 times solubilization cycles at 900°C and 975°C during different times and aged at 500°C in 3 consecutive cycles of 1 hour each.*

This situation seems to indicate that it is not possible to put all the available solute for the aging in a single thermal cycle into solution, but repetition of the cycles accomplishes this task. The structure of the alloy resists four thermal cycles without showing any sign of deterioration in hardness.

The fact that it is not only the high temperature that causes the dissolution of precipitates but also the repetition of cycles formed by the conjugation of high solubilization temperatures applied at very short times is also verified. This condition operates by generating greater availability of hardening solutes after each cycle. One possible explanation for this event might be that having coherent and non-coherent precipitates available after each cycle increases the volume of precipitates going into solution.

It is also shown that by increasing residence time at 975°C. (red line) it is not possible to further harden the alloy because when a sample is subjected to a temperature of 975°C and times of 120 minutes, the hardening is constant in each cycle (as seen in the red line in the graph of Figure 3). This behavior would indicate that there is no justification for its use.

There are other questions to answer: What happens to microstructure when subjected at 975°C for long periods of time? The answer is that there is a fixed and unique volume of precipitates to dissolve at each temperature and for that volume of precipitate, there will always be a single time. To apply higher times (in this case 120 minutes), does not contribute to more dissolution of second phases.

It is also verified that a plastic deformation (60%) helps precipitation kinetics, proving that generation of microstructural defects influences precipitation kinetics.

5. Conclusions

From the study of the CuCrZr thermotratable alloy, it is evident that successive solubilized and aged thermal treatments affect the microstructure of the alloy.

Therefore, tests performed indicate that for each solubilization temperature, there is a single treatment time. These two parameters are the variables that determine the volume of precipitates hardeners available to increase hardness in each cycle. It is further observed that plastic deformation after solution treatment increases precipitation kinetics, by increasing the number of nucleation sites for coherent precipitates.

References

[1] Yang He, Zhihong Jia, Robert E. Sanders, Yingying Liu, Lipeng Ding, Yuan Xing, Qing Liu, Quantitative study of dissolution of Mg_2Si during solution treatment in AA6014 alloy, Journal of Alloys and Compounds, Volume 703, 5 May 2017, Pages 272-279.

[2] Lombardia, D. Sediakob, A. Machina, C. Ravindrana, R. MacKay. Effect of solution heat treatment on residual stress in Al alloy engine blocks using neutron diffraction, Materials Science and Engineering: A, Volume 697, 14 June 2017, Pages 238-247.

[3] R. Fernandez Gutierrez, F. Sketb, E. Maire, F. Wilde, E. Boller, G. Requena. Effect of solution heat treatment on microstructure and damage accumulation in cast Al-Cu alloys. Journal of Alloys and Compounds 697 (2017), Pages 341-352.

[4] Seong-Jong KIM, Seok-Ki JANG. Effects of solution heat treatment on corrosion resistance of 5083F Al alloy. Trans. Nonferrous Met. Soc. China 19 (2009). Pages 887-891.

[5] A. Niklas, S. Orden, A. Bakedano, M. da Silva, E. Nogués, A. I. Fernández-Calvo. Effect of solution heat treatment on gas porosity and mechanical properties in a die cast step test part manufactured with a new AlSi10MnMg(Fe) secondary alloy Materials Science & Engineering A 667 (2016) 376–382.

[6] Yi-Ling Chang, Fei-Yi Hung, Truan-Sheng Lui. Enhancing the tensile yield strength of A6082 aluminum alloy with rapidheatsolutionizing. Materials Science & Engineering A 702 (2017) 438–445.

[7] T. A. Costa, O. L. Rocha, A. Garcia. Effect of solution time in T6 heat treatment on microstructure and hardness of a directionally solidified Al–Si–Cu alloy. Journal of Alloys and Compounds.

[8] I. Ivanić, S. Kožuh, F. Kosel, B. Kose, I. Anžel, M. Bizjak, M. Gojić. The influence of heat treatment on fracture surface morphology of the CuAlNi shape memory alloy. Engineering Failure Analysis 77 (2017) 85–92.

[9] A. Chbihi, X. Sauvage, D. Blavette. Atomic scale investigation of Cr precipitation in copper. Acta Materialia, Volume 60, Issue 11, June 2012, Pages 4575–4585.

[10] Derek E. Tyler, ed. Properties and Selection- Nonferrous Alloys and Special-Purpose Materials, Vol 2, ASM International, Materials Park, Ohio, 2004, p. 831–995.