KINETIC STUDY OF AN AA7075 ALLOY UNDER T6 HEAT TREATMENT

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Summary: High performance aluminum alloys are widely used in aircraft industry because of their high strength, low density and good response to heat treatments. The kinetics of phase precipitation of an AA7075 alloy under T6 heat treatment were characterized in three different solutions and aging conditions. Hardness and tensile testing were performed to determine the mechanical properties. Characterizations of the precipitation states was carried out by scanning electron microscopy (SEM). In the optimal T6 condition, AA7075 samples obtained a hardness value of 91.72 HRB after solution treatment at 465 ºC/90 min and aging treatment at 120 ºC/12 hours. The hardness values affect significantly the tensile strength of the AA7075 alloy, being possible to obtain an UTS value of 720 MPa.

Keywords: T6 heat treatment, AA7075, mechanical properties, precipitation kinetics.

1. INTRODUCTION

Aluminum is the non-ferrous metal most used worldwide, and in the last years, its consumption increased significantly. Aluminum alloys are very attractive to aeronautic and automobile industry because of their good mechanical properties and their low density [1, 2].

Alloys based on the Al-Zn-Mg-Cu system, such as the 7xxx series, are used to fabricate aircraft parts with T6 heat treatment. The good response to the temper is because the precipitation of second phases, such as $MgZn_2$, that increase the mechanical properties [1-3].

The common T6 heat treatment involves solution treating the AA7075 alloy at 480 ºC for 1 h, rapid quenching in water and age hardening at 121 ºC for 24 h [4].

In high alloys aluminum performance, such as the AA7075 alloy, heat treatments are very important and represent an expensive step of the processing, being limited by the time and the temperature applied. The aim of this study is to investigate the relationship between the variation, from the common T6 treatment, of the processing parameters (solution and aging treatment temperature) on the microstructure and on the mechanical properties of the alloy.

2. EXPERIMENTAL PROCEDURE

Commercial AA7075 alloy in the form of cylindrical bars of 16 mm diameter was used to carry out this study. The chemical composition determined by spectral analysis is shown in Table 1.

Table 1. Chemical composition (wt%) of AA7075.

Cu	Mn	Mg	Cr	Zn
1,87	0,28	2,4	0,24	5,30

This study was performed in two steps. First, the solution treatment was investigated and, in the second step, the aging treatment was analyzed.

The samples were exposed to three solution treatment temperatures, 465, 475 and 485 ºC and then they were artificially aged at 120 ºC for different periods. The scheme of the solution treatment procedure is shown in Figure 1.

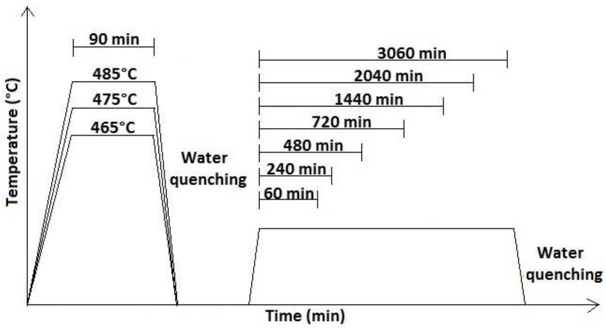

Figure 1. Scheme of the solution treatments procedure.

After analyzing the solution effect on the hardness, different aging treatment temperatures were investigated. Therefore, the samples were exposed to solution treatment at 465 ºC and then the aging treatments were performed at 90, 120 and 180 ºC for different periods. The scheme of the aging treatment procedure is shown in Figure 2.

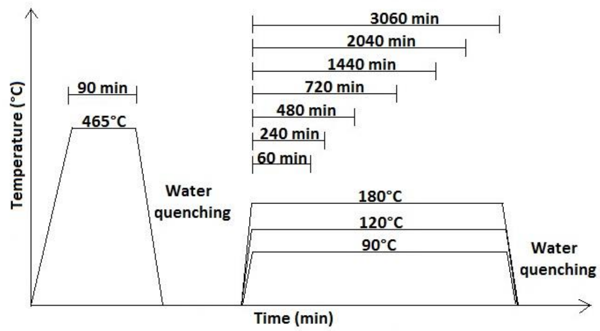

Figure 2. Scheme of the aging treatments procedure.

The mechanical properties measurements were made at ambient temperature. The heat-treated specimens were cut, prepared and etched with Keller's and the microstructural characterization were made by scanning electron microscopy (SEM).

Based on hardness (Rockwell B) and microstructural results (SEM), the optimal T6 treated sample, solution treated at 465 ºC/90 min and aged at 120 ºC/12 h, was analyzed by X-ray diffraction technique and tensile tests.

3. RESULTS AND DISCUSSION

Fig. 3 shows the variation of hardness with aging times in the 7075 Al alloy previously solution treated at 465, 475 and 485 ºC and aged at 120 ºC.

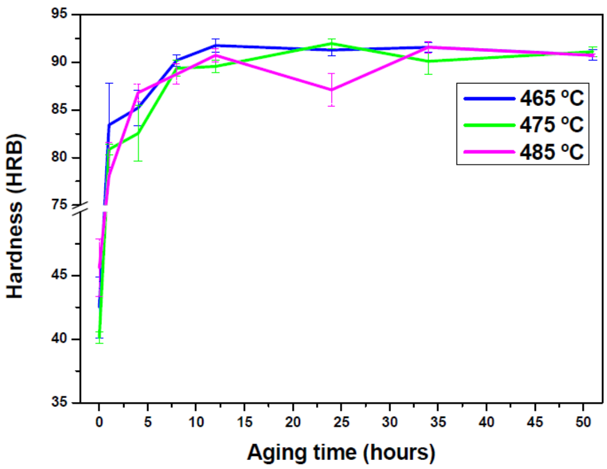

Figure 3. Variation of hardness with aging time to three solution treatment conditions.

The similarity of the curves obtained at different solution treatment temperatures may be associated with the dissociation of a similar amount of intermetallic phases, which are responsible for the formation of the fine precipitates in the aging step.

At 465 °C solution temperature, the hardness peak was in 12 hours of aging, remaining relatively stable up to the period of 51 hours. At 475 and 485 ºC solution temperature, the samples showed hardness peaks in 24 and 34 hours, respectively.

In the second step of this study, the 465 ºC solution temperature was applied because it was the one that presented the hardness peak with the shortest time. Fig. 4 shows the variation of hardness with aging times in the alloy solution treated at 465 ºC and aged at 90, 120 and 180 ºC.

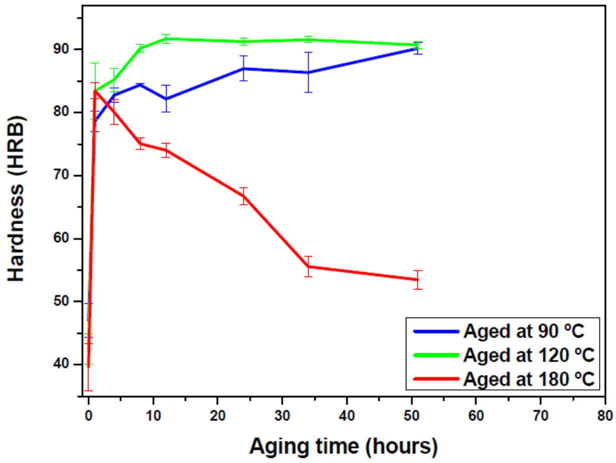

Figure 4. Variation of hardness with aging temperatures of 90, 120 and 180 ºC.

At 90 °C aging temperature the maximum hardness was 90.20 HRB after 51 hours of aging. At lower aging temperatures, the samples showed a slow hardness increase over the time due to the low diffusion rate.

On the other hand, at 120 °C aging temperature the maximum hardness was 91.72 HRB after only 12 hours of aging. The higher efficiency presented in this condition may be associated with the combination of moderate diffusion and nucleation rates at this temperature.

At 180 °C aging temperature the maximum hardness was 83.46 HRB after 1 hour of aging. The hardness decrease over the time of aging, indicating the phenomenon known as super-aging. The high temperature and the long aging times favor the growth of the precipitates, which generates the reduction of the resistance due to the low efficiency in preventing the movement of the dislocations during the deformation [3].

Fig. 5 shows SEM photographs of solution treated (465 ºC/1 h) samples aged at 90, 120 and 180 ºC in their hardness peak. The results suggest that the precipitates are η' and it is possible to observe a higher density within the grain boundary of the alloy [5, 6]. In the sample aged at 90 ºC/51 h (Fig. 5a) there are few and coarse precipitates on the matrix. In this condition, there is a higher degree of saturation witch increases the nucleation rate, however, the diffusion rate is low due to the low temperature, which results in a lower precipitation rate (51 hours to achieve in the hardness peak). In this case, the diffusion rate controls the precipitation process, causing it to occur slowly, damaging the growth of several nuclei by the matrix.

In the sample aged at 120 °C/12 h the precipitates are finely distributed throughout the matrix (Fig. 5b). There is an optimum balance between the diffusion rate and the supersaturation of the elements in the matrix. The higher saturation degree promotes nucleation throughout the matrix and the higher diffusion rate contributes to the growth of the nuclei formed, resulting in small precipitates with greater dispersion throughout the matrix.

In the sample aged at 180 °C/1 h the precipitates are coarse and are present in the grain boundaries (Fig. 5c). Because of the high aging temperature, the diffusion rate increases, but the alloy has a lower saturation degree, which results in a low nucleation rate. Precipitation occurs in places of greater energy, such as in the grain boundaries.

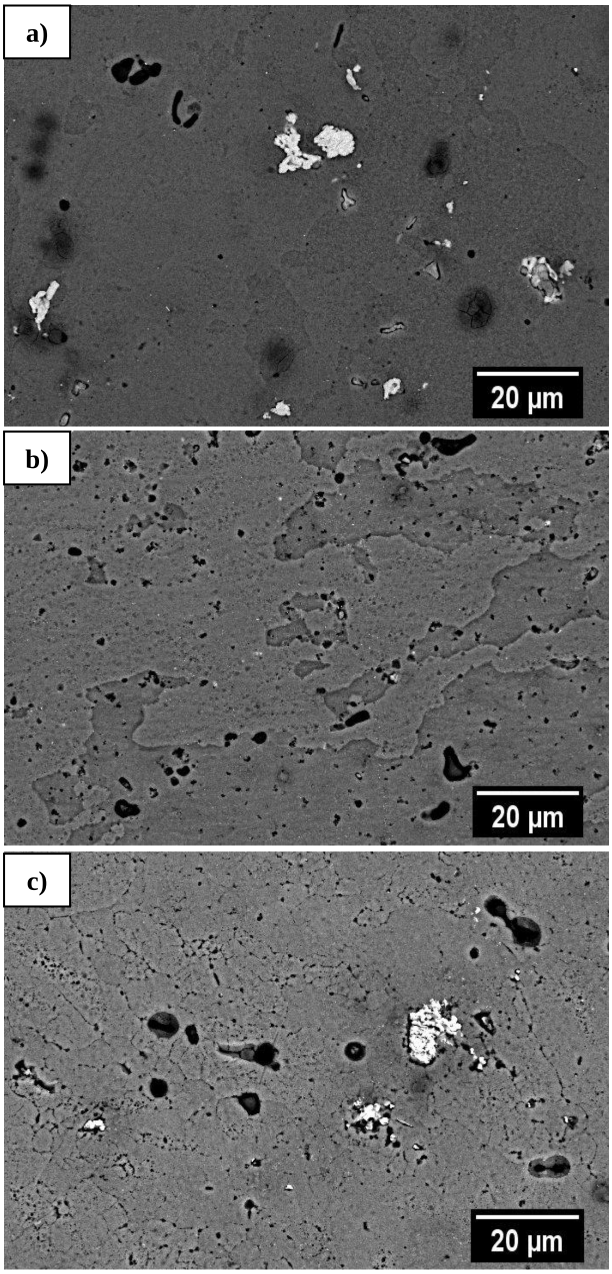

Figure 5. SEM photographs of solution treated at 465 ºC/1 h samples aged at a) 90 ºC/51 h, b) 120 ºC/12 h and c) 180 ºC/1 h.

Therefore, the T6 treatment condition that favored the hardness increase and lower energy expenditure was the T6 treatment using the aging temperature of 120 ºC/12 h. Fig. 6 shows the analysis by dispersive energy spectroscopy of the precipitates presents in this sample and it was possible to identify them as a precipitate rich in Mg and Zn. Another dispersive energy spectroscopy analyzes shown precipitates rich in cupper, as expected.

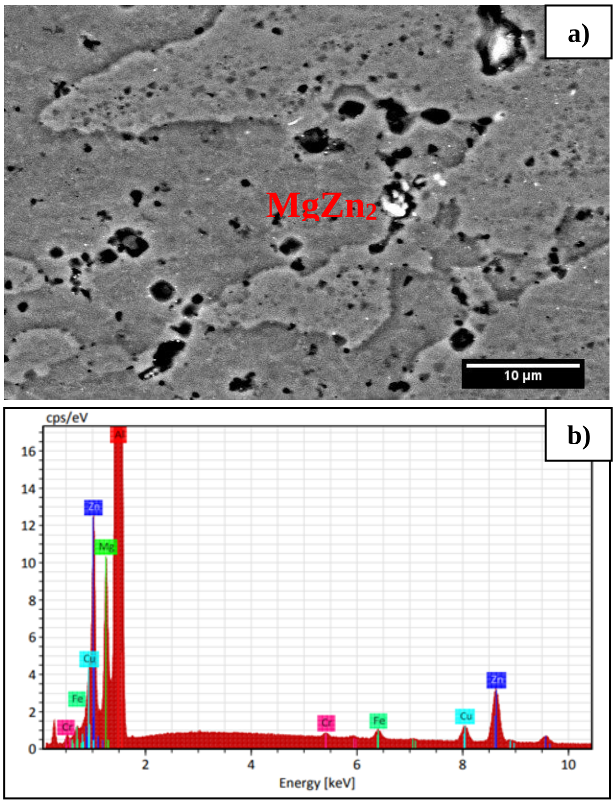

Figure 6. a) High magnification SEM microphotograph and b) EDS analyses of the sample aged at 120 ºC/12 h.

X-ray diffraction analysis identified only the Al-α phase. It may be associated with the greatest precipitates refinement and low quantity, making no possible to identify the precipitate peaks (Fig. 7).

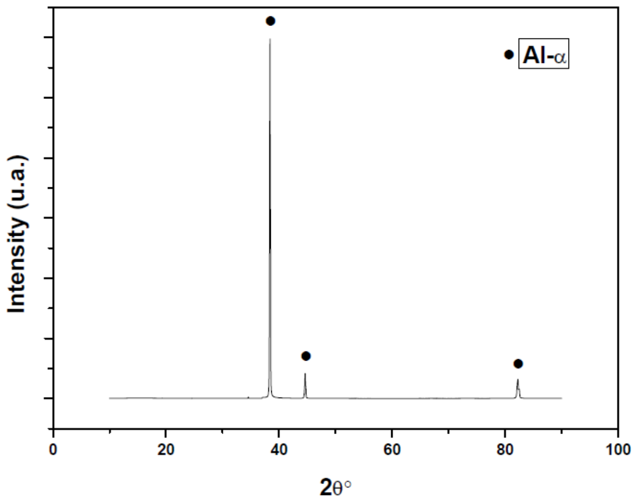

Figure 7. X-ray diffraction analysis to the sample aged at 120 ºC/12 h.

Fig. 8 shows the tensile properties of the optimum T6 treated specimen, solution treated at 465 ºC/90 min and aged at 120 ºC/12 h in comparison with the AA7075 annealed alloy (300 ºC/1 h). The T6 heat-treated specimen shows a high resistance (ultimate stress of ~720 MPa and yield stress of ~652 MPa) due to the effective precipitation process in comparison with the annealed specimen (ultimate stress of ~305 MPa and yield stress of ~213 MPa). This increase in the mechanical resistance is due to the effective barrier to the movement of the dislocations provided by the presence of the precipitates.

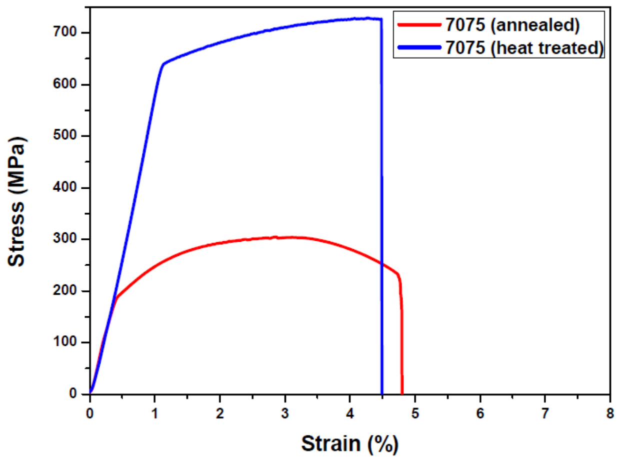

Figure 8. Tensile properties for 7055 alloy heat treated and annealed.

The T6 tensile specimen and the annealed tensile specimen has a hardness value of 91.72 HRB and 42.28 HRB, respectively. These results agreed with the literature [4], where the increase of hardness of the alloy promotes a linear increase in the yield stress and in the ultimate tensile stress. Therefore, the hardness measurements could be used as a predictor for tensile strength of the AA7075 alloy.

4. CONCLUSIONS

Heat treatments applied in AA7075 alloys are arguably essential to confer to these materials their high mechanical strength; however, these treatments will cause a cost increase, mostly due to the energy associated with the process, what will affect the final product cost. Therefore, this paper studied the influence of the solution and aging treatment temperature during T6 heat treatment.

The small variation in the solution treatment temperature (± 10 ºC) is not able to promote a significant change in the saturation degree of the alloy. Consequently, the hardness values will not change significantly after the same aging treatment condition.

The aging treatment temperature has an important influence on the final microstructure and on the mechanical properties. At 90 ºC the aging process is extremely slow, making it take a long time to obtain an optimal hardness level. In addition, at 180 ºC the super-aging phenomenom occurs. Then, the optimum aging temperature is 120 ºC/12 h.

The hardness values affect significantly the tensile strength of the AA7075 alloy.

5. REFERENCES

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