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MODIFICATION OF A-6061 T6 ALUMINUM USING AN AL-MG-CE, AL-LI MASTER ALLOY

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ABSTRACT: This research analyzes the effect and modification of commercial aluminum A-6061 T6 through the addition of an Al-Mg-Ce and Al-Li master alloy with the aim of improving its mechanical properties with the influence of T6 heat treatment. The study includes the production of an Al-Mg-Ce and Al-Li master alloy through the melting of beverage cans. To obtain the Al-Mg-Ce master alloy, cerium oxide was reduced aluminothermically and magnesium was added during the melting of the cans. For the Al-Li master alloy, high--purity lithium was added to the aluminum obtained from the melting of the cans. The master alloys developed were then characterized, and the commercial A-6061 T6 aluminum was added to the master alloys.--Li master alloy, high-purity lithium was added to the aluminum obtained from the melting of cans. The master alloys developed were then characterized and added to commercial A 6061 T6 aluminum. Once solidified, a T6 solution and aging treatment was applied. The mechanical properties of the modified A-6061 T6 aluminum were obtained, as well as the microstructural changes present due to the addition of cerium, Mg, and lithium and the T6 heat treatment. The results obtained show that the incorporation of Ce, Mg, and lithium into the A-6061T6 alloy causes changes in the morphology of silicon, as well as in the distribution of the phases present in the modified aluminum. This increases its hardness and improves its mechanical properties. T6 treatment improves the distribution of these precipitates, maximizing mechanical properties. This research represents a promising strategy for developing 6000 series aluminum alloys suitable for aerospace applications and the manufacture of electrical microcomponents where weight reduction and improved mechanical performance are increased.

KEYWORDS: Al-6061 T6, T6 heat treatment, Al-Mg-Ce, Lithium.

INTRODUCTION

Aluminum has a density of 2700 kg/m3, which is one-third the density of steel, and a modulus of elasticity of 10 x 10^6 psi (70 GPa). Although aluminum alloys have lower stress properties than steel, their specific strength (or strength-to-weight ratio) is excellent [1]. The excellent corrosion resistance of pure aluminum is largely due to its affinity for oxygen [2]. Although it is commonly found in the construction industry, the physical properties of aluminum and its alloys make it an essential material for the transportation and aerospace automotive sectors. Currently, ways to improve or increase the mechanical properties of aluminum are being researched. One promising avenue, which is still being investigated, is the addition of Al-Mg-Ce and Al-Li master alloys, which increase strength, improve stiffness, reduce density, and improve fatigue resistance [3]. Research has shown that Al--Ce alloys are highly moldable and can form structures in thermodynamic equilibrium and remain so until close to their melting point of 560°C, remaining thermodynamically stable regardless of their mode of preparation. There is also renewed interest in the development of precipitation-hardened Al-Li alloys due to their high Young's modulus and low density [4].

EXPERIMENTAL DEVELOPMENT

The experimental development was carried out in six stages

Stage I. Obtaining high-purity aluminum from beverage cans.

For this research, it was necessary to collect this type of packaging in order to start with a less expensive option and thus make a real contribution to caring for the environment. Once the raw material for the work had been obtained, it was melted in a floor furnace, where aluminum ingots were obtained from beverage cans, Figures 1 and 2. They show the melting and obtaining of ingots to make the master alloy. The melting was carried out at temperatures of 750ºC in order to increase the fluidity of the liquid metal when pouring into the graphite molds.

Figures 1 and 2. Photograph showing the melting of aluminum cans in a floor furnace and the production of ingots for the established study.

Stage II. Preparation of Al-Mg-Ce and Al-Li master alloys from high-purity aluminum.

The melting was carried out in a THERMOCIENTIFIC laboratory muffle furnace. The amount of aluminum ingot was 600 g, 60 g of magnesium, and 120 g of cerium oxide. The temperature was 750°C, with stirring applied for better dissolution. For the Al-Li master alloy, 600 g of aluminum ingot and 60 g of high-purity lithium were melted at a temperature of 750°C, and mechanical agitation was applied to obtain a homogeneous mixture. Figures 3 and 4 show the additives and the agitation performed.

Figure 3. Photograph showing the magnesium, cerium oxide, and lithium used to produce the Al-Mg-Ce and Al-Li master alloys.

Figure 4. Photograph showing mechanical stirring during the production of the master alloys.

Stage III. Addition of master alloys to commercial aluminum. 6061T6

The melting was carried out at a temperature of 750°C. In this case, 700 g of commercial aluminum A-6061T6 and 300 g of Al-Mg-Ce master alloy were melted, and to obtain the other melt, 700 g of commercial aluminum 6061T6 was melted with 300 g of lithium master alloy.

Stage IV. Obtaining test specimens for characterization.

The test specimens for characterizing the tests obtained in the fusion of 6061T6 aluminum modified with the master alloys were cast in a metal mold and, after solidification, were cut for analysis under a microscope, hardness testing, and stress testing. Figure 5 shows the muffle furnace used to obtain the samples for characterization, and Figure 6 shows the different samples that were needed to carry out the characterization in this study.

Figure 5.Modified with master alloy aluminum 6061T6 melting

Figure 6. Representation of test pieces obtained for characterization

Stage V. Application of T6 Heat Treatments.

T6 solubilization and aging heat treatment was applied to commercial 6061T6 aluminum modified with the addition of Al-Mg-Ce and Al-Li master alloys.

The heat treatment parameters were as follows:

- Solution treatment at 530°C for 1.5 hours.
- Quenching in water.

- Aged at 230ºC for 1.5 hours.
- Cooling to room temperature.

Figures 7 and 8 show the solubilization and aging treatments performed on 6061 aluminum modified with Al-Mg-Ce and Al-Li master alloys.

Figure 7. Solubilization and water quenching.

Figure 8. Aging and cooling to room temperature.

Stage VI. Characterization of samples.

The chemical analysis was performed on the original sample of commercial aluminum 6061T6 using a **Spark Emission Spectrometer** model **LAB LAVM11.** The selected samples were prepared metallographically to be analyzed first under an optical microscope to observe the microstructure and analyze its evolution during the heat treatment applied. A scanning electron microscope (SEM, Scanning Electron Microscopy) was used to observe the microstructure and analyze its evolution during the applied heat treatment. **The** modified 6061T6 aluminum was tested using a Rockwell hardness tester on the HR30T scale and was tested in a Tinius Olsen tensile testing machine with a load capacity of 10,000 kgf - 60,000 kgf. The maximum breaking load was obtained using this equipment.

RESULTS AND DISCUSSION

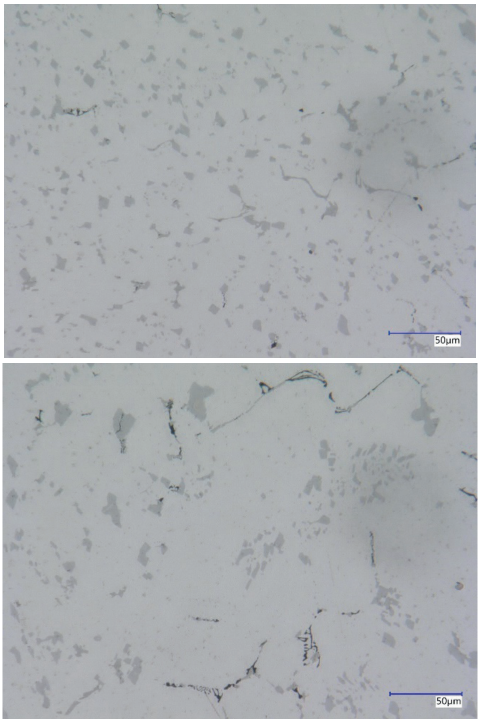
Chemical analysis

The chemical analysis was performed on the original sample of commercial aluminum 6061T6 using a LAB LAVM11 spark emission spectrometer. Based on the results obtained, it is considered that it complies with the chemical analysis based on the A-6061T6 aluminum specification.

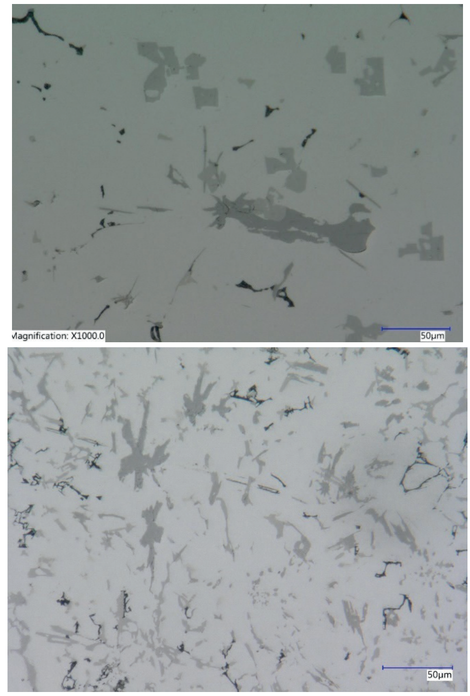
Yes	Fe	Cu	Mg	Cr	Zn	Ti
0.62	0.7	0.29	0.95	0.09	0.15	0.009

Optical Microscopy Results

The metallographically prepared samples were observed under a KEYENCE optical microscope, with the results obtained at 1000X magnification shown in the photomicrographs. Figures 9 and 10.



Figures 9 and 10. Photomicrographs of commercial aluminum alloy A 6061T6 at 1000x. Aluminum and silicon matrix.



Figures 11 and 12. Photomicrographs of modified commercial aluminum alloy A 6061T6 at 1000x. Aluminum matrix and change in silicon morphology showing dark areas of the magnesium phase.

Figure 11 shows the microstructure of A6061T6 aluminum modified with an Al-Mg-Ce master alloy, while Figure 12 shows A6061T6 aluminum modified with an Al-Li master alloy.

Hardness test results

The following results are the hardness values obtained for A-6061T6 aluminum and A-6061T6 aluminum modified with the Al-Mg-Ce and Al-Li master alloys.

Identification	HB hardness
Aluminum A-6061T6	90
Aluminum A-6061T6 modified with Al-Mg-Ce master alloy	96
Aluminum A-6061T6 modified with Al-Li master alloy	84

Tensile Test Results

The maximum load results obtained for aluminum A-6061T6 and aluminum A-6061T6 modified with Al-Mg-Ce and Al-Li master alloys are shown below. These tests were performed on a Tinius Olsen 301 tensile testing machine in accordance with ASTM E-8.

Identification	Maximum load Kgf
Aluminum A-6061T6	1195
Aluminum A-6061T6 modified with Al-Mg-Ce master alloy	1214
Aluminum A-6061T6 modified with Al-Li master alloy	868

CONCLUSIONS

It is possible to prepare master alloys with various types of elements such as magnesium, cerium, lithium, zinc, and strontium, and add them to commercial aluminum in order to improve its mechanical properties. The following conclusions can be drawn from this research.

- It was observed that in the microstructures obtained in A-6061T6 aluminum to which Al-Mg-Ce and Al-Li master alloys were added, the morphology of the silicon was modified by these master alloys.
- The best hardness value was in A-6061T6 aluminum modified with the Al-Mg-Ce master alloy, but not with the Al-Li master alloy.
- The best value in the tensile test was in A-6061T6 aluminum modified with the Al-Mg-Ce master alloy, and the lowest value was in A-6061T6 aluminum modified with the Al-Li master alloy.
- The mechanical properties of commercial aluminum A-6061T6 were improved with the addition of the master alloy Al-Mg-Ce, while the other master alloy Al-Li did not exceed the properties of commercial aluminum A-6081T6.
- The incorporation of lithium into commercial aluminum was minimal. I attribute this to the fact that lithium has a very low density and tends to oxidize very quickly. Its incorporation into aluminum could be improved by applying a protective atmosphere and adding a higher percentage of lithium to the molten aluminum.

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