Homogenization heat treatment effects over the structure of 2724 cast aluminium alloy semi-products

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Abstract. This project showcases the effects of the homogenization treatments applied to 2724 cast aluminium alloy semi-products, as well as the results regarding the resistance and plasticity improvement of these semi-products. These results have proven the validity of the initial processing hypothesis, which states that certain modifications of the crystalline structure can lead to the improvement of the characteristics mentioned above. A highly resistant 2724 aluminium alloy sample, representing the Al-Cu-Mg system, was used for this experiment. At a structural level, the alloy is made of aluminium based solid α solution grains and a series of binary, ternary or complex intermetallic phases that can either be soluble or insoluble. This type of alloy is mostly used in the machine building or aeronautics industry. The results are according to the microstructural observations, the homogenization heat treatment effect leading to the removal of any chemical heterogeneity (dendritic segregation) and a balanced structure made of polyhedral crystals and a homogeneous dispersion throughout the whole mass of the alloy.

1. Introduction
The homogenization heat treatment has the purpose of removing any chemical inhomogeneity (dendritic segregation) and reaching a balanced polyhedral crystals structure. The chemical inhomogeneity can be found in single-phase alloys as well as by-phasic alloys, thus making it necessary for the inhomogeneity to be eliminated (diminished), so it becomes necessary to remove the primitive limits of the cast grains as well as modifying the fibrous structure of the semi-products, seeing as how these are the main factors which determine the characteristics variation. Highly resistant aluminium alloy extruded products used in the aeronautical industry are being subjected to various tests. Under pressure, these products must show a good correlation between characteristics such as mechanical resistance, plasticity, tenacity, fatigue resistance and corrosion resistance.

The purpose of heat treatments is to modify the initial structure and characteristics. The homogenization heat treatment applied to cast aluminium semi-products was the object of many scientific researches.

The present paper focuses on the aluminium alloys heat treating process. The material subjected to this experiment was a 7150 Zr 0.13% alloy. The results for the single stage conventional homogenization (figure 1 a, c) were compared to the new two-stage homogenization (figure 1 b, d), the first being pre-treated at 250°C.
Figure 1. SEM pictures of the 7150 alloy’s homogenized microstructure; (a), (c) single stage homogenized sample; (b), (d) two-stage homogenized sample. [1]

The heat resistant Al-Cu-Mg-Fe-Ni aluminium alloy, based on the 2024 alloy, has a complex chemical structure that was reached by dropping the amount of Si impurities and adding Fe and Ni. The 2D70 aluminium alloy is considered to be the most important structural material used in aerospace applications and it has the same room temperature resistance as the 2024 alloy and it can support even higher temperatures than the 2024 alloy. In order to reach an adequate homogenization heat treatment it is necessary to study the cast microstructural intermetallic compounds as the heat treatment goes on. The conventional homogenization heat treatment was done at a temperature of 490°C for 16 hours and the double homogenization heat treatment was done at 490°C for 16 hours, followed by 530°C for 16 hours. [2]

The industrially modified AA5083 aluminium alloy was analysed in the paper [3] and then subjected to a multiple stages homogenization heat treatment. The heat treatments took place at a 430-555°C temperature interval. The industrially modified AA5083 aluminium alloy’s microstructure was investigated using the optical techniques SEM, TEM and microanalysis. The effect that the microsegregations had when applied to the structure of the precipitates was analysed. The constituent components of the Al16(Fe,Mn) and Mg2Si particles were formed in the inter-dendritic regions, while the n-Al11(Mn,Cr)4 dispersions formed in the dendritic cores. Results of the initial cast alloy’s electrical resistance as well as the electrical resistance of the heat treatment affected areas are shown in the paper.

The alloys studied in the paper (6061, 2219, 2014) [4] took form by being melted in an induction furnace and cast into cast iron ingot shaped matrixes. These ingots eventually homogenized at a temperature of about 540°C.

The AA 5052 cast aluminium alloy was homogenized at a temperature of 470°C for 15 hours and air cooled. Five different heat treatments were applied to the laminated alloy at temperatures of 220, 250, 300, 350 and 380°C for 4 hours each. Microstructures and the laminated aspect were observed along the middle sections, parallel to the rolling direction, of the treated samples [5].
The 7B04 cast alloy’s [6] crystalline grains have an average size of 115μm and α (Al) primary and secondary phases’ eutectic structure network situated between granular and interdendritic grains (figure 2).

Figure 2. Microstructural view of the 7B04 cast alloy: (a) dendritic structure; (b) secondary phases [6]

The impact of the electrical current on the toughness and on the morphology of the secondary phases of the 7B04 aluminium alloy, homogenized at 380°-465°C for 2 hours, were closely observed by measuring the electric conductivity, performing hardness tests, X-ray diffraction, SEM and EDS.

The homogenized sample’s area fraction is smaller in secondary phases than the sample that was homogenized under normal conditions at the same temperature. The results show that by raising the temperature from 380°C to 465°C, the electrical conductivity of the sample that was homogenized under normal conditions dropped from 34.9% IACS to 28.7% IACS, hardness grew from 96 HV to 146 HV and the zonal fraction of the secondary phase dropped from 4.5% to 1.89%. [6]

2. Materials and experimental method
The main alloying elements for aluminium are Cu, Mg, and Zn to which Mn, Ni, Cr and Fe are added. Alloying’s purpose is to improve the mechanical properties of aluminium. The most widely used alloys are the Al-Si, Al-Mg, Al-Cu-Mg, Al-Mg-Mn, Al-Mg-Si and Al-Zn-Mg-Cu systems.

The material used for the research is a 2724 highly resistant aluminium alloy of the Al-Cu-Mg system. At a structural level, the alloy is made of α solid solution grains and a series of binary, tertiary or complex intermetallic phases, soluble or insoluble.

This alloy is mostly used in the aeronautical and machine constructing industries, having good mechanical characteristics, high fatigue resistance and good resistance to corrosion.

The microstructural analysis was done by microscopic observation of the cast semi-products samples which were polished and attacked with an attack reagent.

Hardness was determined by an F scaled Rockwell durometer.

3. Experimental Results
Experimental research focuses on the impact that the homogenization heat treatments have on the structure and the characteristics of the cast aluminium semi-products, especially the 2724 ones.

Figure 3 shows a 2724 aluminium alloy sample, collected from a 150mm diameter cast semi-product, will be initially used to emphasise a crystalline structure.

Figure 4 showcases the microstructural level of the 2724 alloy sample before the heat treatment. The grains are big, elongated according to the hereditary cast grains which are subdivided in aggregate subgrades.

The homogenization heat treatment was made in a hot air furnace, the semi-products being placed at an equal distance from one another in order to be homogenized uniformly, the temperature was permanently monitored using 5 K-thermocouples.
The thermocouples were mounted at the ends of the semi-products, leaving a distance equal to half of the semi-products’ diameter (if the mounting was made at the end where the casting began) or a maximum equal distance (if the mounting was made at the end where the casting ended).

Figure 3. Research used 2724 alloy sample

Figure 4. The microstructural level of the 2724 alloy sample before the heat treatment

The homogenization treatment was applied to 3 batches of samples at the temperatures of 470°C (1st batch of samples), 480°C (2nd batch of samples) and 490°C (3rd batch of samples), 7 hours heating, 16 hours maintaining, adding up to a total of 23 hours of treatment.

The 2724 alloy sample (Fig. No.3) was tested for hardness using a CV100 lab Rockwell hardness tester. An acting force of 588N was used on a 1/16 inch diameter ball for 5 seconds. In table no. 1 we can see the values of the Rockwell hardness as well as the equivalent for the Brinell hardness, and to make sure that the results are real, the hardness tests were done 4 more times on the same product ending with an overall average. The results are shown in table 1.

Table 1. Rockwell and Brinell hardness values for the 5 tests as well as their average

| Sample identification | Hardness | I  | II | III | IV | V  | Average Hardness, HRF | Equivalent HB(500kgf) |
|-----------------------|----------|----|----|-----|----|----|------------------------|-----------------------|
| Sample 1              | HRF      | 73 | 75 | 75.3| 74 | 75.6| 74.58                  | 71                    |
| Sample 2              | HRF      | 75.2| 77 | 77.5| 77 | 76  | 76.5                  | 72                    |
| Sample 3              | HRF      | 77.1| 81.8| 79  | 78.8| 77.5| 78.8                  | 73                    |

Figure 5. The 2724 alloy sample at a microstructural level after the homogenization treatment
The hardness tests showed that the 3rd batch of samples, heated at 490°C (homogenization temperature of 490°C and varied between 485 and 499°C), had the best results. Samples were collected, from the 3rd batch of the treated samples, for elongation tests and microscopical analysis (figure 6).

The elongation test results are shown in table 2, determining the elongation at break and the elasticity module.

Figure 5 showcases the homogenized sample alloy. This is a balanced structure made of polyhedral crystals. The result of the heat treatment is the removal of any chemical heterogeneity (dendritic segregation).

![Figure 5. Homogenized sample alloy](image)

**Figure 6.** Elongation at break sample

In order to emphasize the way polycrystalline metals act when under mechanical stress, elongation at break is used as a reference point.

**Table 2.** Elongation at break results

| Sample identification | Rm, MPa | A, % | E, MPa |
|-----------------------|---------|------|--------|
| Sample 3              | 250,77  | 12   | 16427  |

4. Conclusions

When picking aluminium alloys with the purpose of making products for the aeronautical industry, one must keep in mind that these alloys need to be highly resistant to mechanical stress, corrosion resistance, high fatigue resistance as well as a highly resistant to heat.

The experimental results, regarding the improvement of the resistance and plasticity characteristics as a result of the homogenization heat treatments, for the analysed cast alloy semi-products showed that certain modifications of the crystalline structure can lead to the improvement of these characteristics.

By applying homogenization heat treatments to the semi-products, most dendritic segregations were removed and the optimal temperature for the heat treatment to succeed was set around 490°C.

Best hardness and elongation at break values as well as a satisfying plasticity were reached throughout the homogenization heat treatments applied to the aluminium alloy samples.

References

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