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EFFECTS OF HOMOGENIZATION PROCESS OF BILLET CASTING ON MECHANICAL PROPERTIES OF EXTRUSION PRODUCT

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ABSTRACT

Aluminum extrusion industry has a large processing volume today due to the widespread use of aluminum, the development of processing methods with the developing technology and the ability to make the raw aluminum with the desired properties by alloying method. The homogenization process is a heat treatment method that enhances the extrusion industry, improves the extrudability of raw materials, and helps address issues related to dendritic structures and grain boundaries in the final products. Applying this method to the raw material increases both the profitability and ease of the process. The fundamental properties of aluminum alloys, the methods and parameters used in the extrusion process, and the preheating treatments applied during the process were utilized in the production of billets and the homogenization process. Tensile and hardness test results were analyzed for samples obtained through the extrusion method from both homogenized and non-homogenized raw materials.

1. INTRODUCTION

Aluminum and its alloys are widely used in industrial applications and everyday life due to their superior physical properties. Owing to their many advantageous characteristics, such as low corrosion resistance, lightweight nature, durability, low density, and ease of processing, aluminum finds extensive applications in various fields, including automotive, construction, aerospace, and defense industries. The increasing demand for aluminum and the varying geometries and physical properties of desired products have led to the realization that a single method cannot meet all demands. This has necessitated the development of specific manufacturing methods and the diversification of the techniques employed for processing these products. Among aluminum alloys, the 6xxx (AlMgSi) series, which has the highest extrudability, is the most commonly used alloy type in extrusion processes. This alloy is widely utilized in extrusion due to its properties, such as high plastic deformability, superior surface quality, and the ability to increase hardness through artificial and natural aging heat treatments [1]. The use of non-homogenized raw materials in production can lead to the aforementioned issues, prompting scientists to develop a heat treatment method called homogenization to eliminate unstable structures in raw materials. Homogenization involves heating the material to a specific temperature followed by cooling. This process helps to eliminate density variations in the dendritic structure, dissolve unstable phases formed during solidification, and create stable precipitates that positively influence the reduction of the alloy's plastic deformation resistance. In complex alloy systems, there are also stable phases that do not dissolve and reduce the material's ductility alongside unstable compounds. The homogenization process aids in reducing the aspect ratios of these alloys, thereby increasing ductility [2]. Wrought alloys can be cast as billets and subjected to plastic deformation to achieve the desired form. Casting alloys, on the other hand, are poured into molds that match the geometry of the intended part and then undergo solidification. In forging alloys, microstructural discontinuities can be eliminated through applied plastic deformation. For casting alloys, the desired mechanical properties are typically achieved through subsequent heat treatments [3].

Billet casting is not performed in a fixed diameter. Billets of different diameters and lengths can be cast according to the needs and orders of the companies. In order to reduce production costs and standardize production quality, large aluminum extrusion companies provide the billets they need by casting billets in-house. Billet casting in different diameters can be realized only by changing the casting mold. Billets need to be homogenized to have better mechanical performances. The purpose of subjecting the raw material to the homogenization process is to eliminate the density differences in the dendritic structure, to dissolve the unstable phases formed during solidification and to form stable precipitates that will positively affect the extrusion conditions of the alloy to be used. In addition to improving the mechanical properties of raw materials subjected to the homogenization process, the extrudability of the raw material can also be increased. Increasing

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extrudability is an important differentiator for increasing production efficiency and this factor can be improved by homogenization process. Ensuring parameters such as uniform grain structure, surface quality and homogenization under appropriate conditions during casting helps to increase the production per unit time, to produce with low extrusion pressure, to provide the desired dimensional tolerances, to obtain a quality surface without cracks and tool marks and to produce products with high strength [4]. 6xxx series alloys contain silicon, magnesium and small amounts of Fe, Cu and Mn as the main alloying elements. Due to the diversity of alloying elements, many different phase precipitations occur during solidification and subsequent cooling processes. The intermetallic components dominating the structure of the precipitates are of the AlFeSi type [5]. The AlFeSi phase plays an important role in the microstructure of aluminum alloys. These structures can influence the properties of the material in subsequent fabrication steps and play a major role in the quality of the material [6].

In this study, 6063 AlMgSi alloy, which is widely used in extrusion industry, was used. The products obtained from two different cast billets, Lot1 material that will be subjected to the homogenization process and Lot2 that will not be subjected to the homogenization process, were examined.

2. MATERIALS&METHOD

The chemical composition of the samples taken from different parts of the molten alloy during the production of raw materials was determined using Exquis T4 Spark Optical Emission Spectrometer (OES). The chemical compositions of the two raw materials obtained after spectral measurements are given in Table1.

***Table 1** Chemical Composition of Lot1 and Lot2 samples*

Alaşım	*Si*	*Fe*	*Cu*	*Mn*	*Mg*	*Cr*	*Zn*
Lot - 1	*0.419*	*0.296*	*0.057*	*0.037*	*0.523*	*0.088*	*0.069*
Lot - 2	*0.448*	*0.328*	*0.098*	*0.083*	*0.559*	*0.011*	*0.78*

Fig. 1. Temperature value of casting process

In the experimental study, casting temperatures were determined as 730°C for the production facility. It can be seen in Figure 1. At the end of the casting process, 4180mm billet was obtained for both billets. The homogenization process of the sample named Lot-1 was carried out at 560°C for 6 hours. Two specimen profiles with the same cross-sectional areas and different shapes were selected and the profiles are given in Figure 2.

The artificial aging process was carried out in a Nevola Thermnevomodel artificial aging oven at 180°C for 6 hours.

Tensile test was carried out for Lot1 and Lot2 samples. Tensile test specimens were prepared using laser cutting and placed in the tensile machine. The tensile tests were performed on the Zwick/Roell Z250 model tensile testing machine with a loading rate of 20 mm/min.

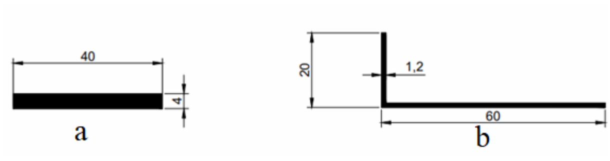

Fig. 2. Profiles of the samples: a-Lot1; b-Lot2

3. RESULTS

Tensile test results of the homogenized Lot1 samples were given in Figure 3.

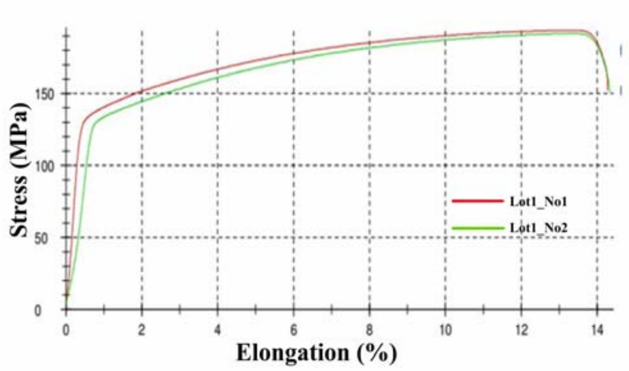

Fig. 3. Tensile Test results of Lot1 samples

When the graph was analyzed, it was determined that three different graph curves were encountered. It was determined that the amount of elongation encountered in the tensile test of the sample named Lot-1 Num-2 showed a difference of 1.5% compared to the other samples. It was considered as a test error during the tensile test and only the results of Lot-1 Num-1 and Lot-1 Num-3 were evaluated in the comparison to be made. The maximum tensile value reached by Lot-1 Num-1 and Lot-1 Num-3 samples subjected to homogenization process was 194 MPa and the maximum elongation was determined as 14.3%.

Tensile test results of the unhomogenized Lot2 samples were given in Figure 4.

Figure 4 shows the Stress-Elongation graph obtained because of the tensile test for three different samples that were not subjected to homogenization process. When the graph was analyzed, it was observed that similar results were obtained with the other test and therefore the results obtained from the sample named Lot-2 Num-2 were not taken into consideration. The maximum stress values reached by Lot-2 Num-1 and Lot-2 Num-3, which are the samples subjected to homogenization process, were determined as 196 MPa and the maximum elongation was determined as 12.2%.

As a result of the tensile experiments, it was observed that the tensile test results applied to the samples subjected and not subjected to the homogenization process showed that the samples with similar chemical composition, produced within the same production parameters and applied the same artificial aging process had very close values. However, it was determined that the homogenization process applied to the material microstructure directly increases the elongation ability of the material. In the experiment, Lot-1 showed an average elongation of 14.3%, while Lot-2 showed an average elongation of 12.2%.

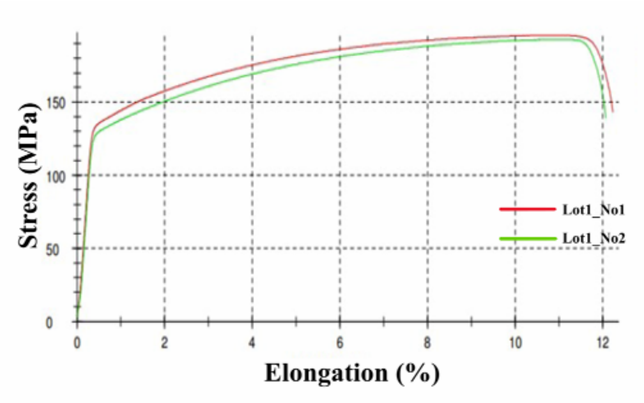

Fig. 4. Tensile Test results of Lot2 samples

After the tensile test, the extruded and artificially aged specimens were subjected to hardness testing. Brinell measurement is generally preferred in determining the hardness of aluminum alloys. This is because properties such as precipitate structures and grain structures may vary locally. The hardness test was performed with Emco Test Durascan 50 G5 model Brinell hardness tester. The hardness test results were given in Figure 5.

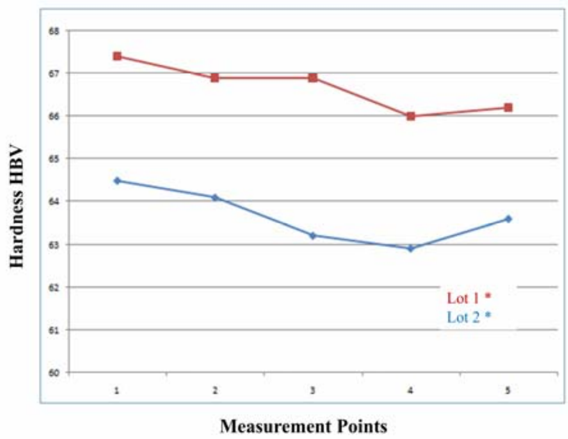

Fig. 5. Hardness Test results

As can be seen in Figure 5, the average hardness of 66.7 HBW was obtained because of the tests applied to Lot-1, while the average hardness of 63.6 HBW was obtained because of the test applied to Lot-2. As a result it could be evaluated that the homogenization process influenced the hardness of the product, although the results of the tests applied to the two samples were very close to each other.

4. CONCLUSIONS

In this study, casting, homogenization, extrusion and artificial aging processes of AA 6063 alloy, which is widely used in extrusion industry, were carried out. The cast billets were divided into Lot numbers and Lot1 was homogenized while Lot2 was not subjected to homogenization process. The raw materials obtained were then extruded under the same extrusion conditions and subjected to artificial aging process. The samples obtained because of all these processes were subjected to tensile and hardness tests and the differences were examined.

As a result of the tensile test, the maximum stress value reached by the homogenized samples was 194 MPa and the maximum elongation was determined as 14.3%. On the other hand, the maximum tensile values of the samples produced with raw materials that were not subjected to homogenization process were determined as 196 MPa and the maximum elongation was determined as 12.2%. As can be seen from the tensile test results, the homogenization process increased the elongation ability of the specimen, but had no effect on the tensile strength. This is a mechanical property obtained as a result of $\beta \rightarrow \alpha$ transformations in the material structure.

The hardness test performed after the tensile test was applied to the sample produced with homogenized raw material and the average hardness of 66.7 HBW was obtained as a result of the experiments, while the average hardness of 63.6 HBW was obtained as a result of the experiment applied to the non-homogenized raw material. As a result of the experiments applied to the two samples, it was seen that the homogenization process applied to each other influences the hardness of the sample.

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