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PRODUCTION AND CHARACTERIZATION OF 2024 ALUMINUM ALLOYS

Cem Misirli*

Trakya University, Edirne, Turkey

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ABSTRACT

This study aims to give theoretical information about the production and characterization of mechanical properties of 2024 aluminum alloys. AA2024 alloy; It consists of components such as aluminum, copper, magnesium and manganese, and the production of the alloy is usually carried out by different methods such as casting, rolling, extrusion and powder metallurgy. The choice between production methods should be made by considering the purpose and properties of the alloy. While the casting method is used for the production of large-sized parts, the rolling method is suitable for the production of thin sheets and strips, and the extrusion method is suitable for the production of profiles and pipes of various shapes. The powder metallurgy method, on the other hand, is carried out by shaping the powdered components of the alloy with a special pressing process and then sintering at high temperature. Alloys produced by this method exhibit high strength properties with their high density and homogeneous microstructures.

The mechanical properties of AA2024 alloy are generally determined using various characterization methods such as tensile test, hardness measurement and fatigue life tests. The tensile test is used to determine the tensile strength, tensile elongation ratio and elastic tension properties of the alloy. The hardness measurement is used to determine the surface hardness of the alloy. Surface hardness can be performed using Brinell, Vickers and Rockwell hardness measurement methods. The fatigue life test is used to determine the fatigue strength of the alloy. In this test, the fatigue life of the specimen under repetitive loads is determined. The mechanical properties of AA2024 alloy may vary depending on production methods, alloy components, temperature and environmental conditions. Therefore, the mechanical properties of the alloy must be optimized for a particular application. 2024 aluminum alloys produced by powder metallurgy method are expected to exhibit high density, homogeneous microstructure and high strength properties as a result of hardness, tensile and fatigue tests.

1. INTRODUCTION

With the development of technology and due to its technical features, aluminum, which is one of the youngest members of the global metal world, is widely used in many areas of the industry. In practice, the ratio of strength to weight (specific strength characteristic) is very large, mild, and aluminum, which is one-third the weight of steel; When alloyed by adding alloying elements, its mechanical properties can be increased to such an extent that it can be compared with steel, aluminum; It has made it very attractive in various branches of industry such as medicine, construction, food, automotive and space industry [1]. The basic alloying element of 2024 aluminum alloys, which is in the 2XXX aluminum class according to the most widely used symbolization sequence in the world for wrought aluminum and its alloys by the American Standards Association (ASA), is copper (Cu). It is common for them to be used in places [2, 3, 4].

The physical, chemical and mechanical properties of aluminum alloys depend on the alloying element and its microstructure.

2XXX: The main alloying element of Al-Cu alloys is copper. Other alloying elements, especially magnesium, can also be found. Brittle and hard phases such as aluminum formed with copper and magnesium ($CuAl_2$, Mg_2Si) increase the strength of the material, but they reduce the machinability (mass deformation) ability of the material as it causes a decrease in ductility [5, 6]. In the studies carried out on the 2XXX group, the desired high ductility and low strength were obtained by disintegrating the $CuAl_2$ and Mg_2Si phases and dispersing them in the α solid solution, and the growth of small sized grains [7, 8].

2024 aluminum alloys, included in the 2XXX class, is a high-strength, low-density aluminum with a tensile strength of approximately 70,000 psi (483 MPa). It has good weldability and formability, while its corrosion resistance is moderate. Moderate corrosion resistance depends on the magnesium element in the alloy and the anti-corrosion coatings. 2024 Al-alloy is widely used in the automotive industry, railcar construction, munitions industry, aircraft fuselage and wings, orthopedic soles, rivets and tractor wheels where specific strength (yield stress/density) and

* Corresponding author. E-mail: cemmisirli@trakya.edu.tr

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specific modulus of elasticity (modulus/density) are important. It is used as [9].

Table 1 *Chemical Composition of 2024 Aluminum Alloy*

Alloy	***Cu***	***Mg***	***Fe***	***Mn***	***Si***	***Zn***	***Ti***	***Other***
AA2024	*3,8-4,9*	*1,2-1,8*	*0,5*	*0,3-0,9*	*0,5*	*0,25*	*0,15*	*0,15*

AA2024 alloy can be produced using various manufacturing techniques. The most commonly used production techniques; casting, rolling, extrusion and powder metallurgy.

Casting: In the casting method, the components of the alloy must be mixed and melted in appropriate proportions. The melting process is carried out at high temperature and the components of the alloy are distributed homogeneously. The molten alloy is then poured into special molds. The mold can be of the desired shape and size. At the end of the casting process, the alloy is cooled and removed from the mold. The resulting cast parts can be used in different ways by being processed later. The casting method is simple and economical as it is done by using traditional casting apparatus in the production of parts where there is no shape and size limit [10].

Rolling:

Rolling is a process used to roll metal into a thin long sheet by passing it through a gap made up of two rollers rotating in different directions (clockwise and counterclockwise). The gap between the two rollers is expected to be smaller than the thickness of the workpiece piece to be formed. The rolling process is a special form of metal forming for shaping large bulk material into more elaborate parts and large lengths of cross-section materials. The rolling process must conform to the rolled work component geometry to ensure the homogeneity of the material and the change in property resulting from the deformation process [11]. Rolling is classified as cold or hot rolling according to the processing temperature. Due to the effect of temperature in the two processes, the grain structure is different. Crystals elongate in the rolling direction. In cold rolling, the crystals retain their elongated shape, while in hot rolling crystals they are reformed after passing through the deformation zone.

Extrusion:

The extrusion method is the process of heating the material under high pressure and passing it through a mold in order to shape it. With this method, the alloy is produced from pre-prepared billets or by means of hot extrusion presses produced by hot pressing of alloy powders. The extrusion process is carried out at high temperature and the hardness of the material is controlled during the extrusion process. Extrusion is one of the methods used to improve the mechanical properties of Metal Matrix Composites. With the hot extrusion method, the oxide layer on the surface of the Al-based composite material can be destroyed and as a result, the interparticle boundaries can be improved. In addition, the agglomeration of the reinforcing element in the matrix structure can be eliminated and thus a structure containing more homogeneously dispersed reinforcement elements can be obtained [12]. The alloy produced by this method is used in various sectors such as aircraft parts, automotive industry, construction materials, sports equipment and defense industry.

Powder Metallurgy: Powder metallurgy is the process of shaping metal or ceramic powders in a mold and firing (sintering) them at a temperature below their melting temperature during or after shaping [13]. Most of the parts produced by the powder metallurgy method are used in the automotive manufacturing sector [14]. The powder metallurgy method comes to the fore in structural materials where shape and size limitations come to the fore and different types of ceramic particles are requested to play an active role in the matrix structure.

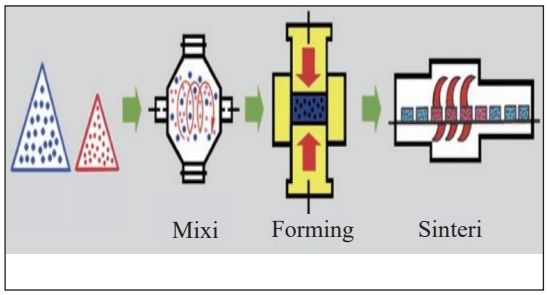

Fig. 1. Powder Metallurgy Production Stages [15]

Aluminum alloys produced by powder metallurgy method have many advantages such as high strength, low density, good corrosion resistance and high temperature resistance. For this reason, it is used in many sectors such as the automotive industry, aerospace industry, electronic devices, medical equipment and defense industry. The fact that aluminum alloys produced by powder metallurgy method offer higher strength, lower weight and higher performance compared to traditional production methods, causes them to be increasingly demanded in the industry.

The mechanical properties of AA2024 alloy are generally determined using various characterization methods such as tensile test, hardness measurement and fatigue life tests.

Hardness is defined as the resistance of a material to friction, abrasion, scratching or deformation. Static hardness measurement methods, which cause deformation on the material with a constant force, are preferred because they give similar results, less damage to the sample and short test time [16]. There are many different hardness measurement methods. Some of those; Rockwell, Brinell, Vickers, Meyer, Berkovich, Instrument trace test (martens hardness), Knoop hardness measurement methods. Brinell test is a test performed by applying a certain load to the surface of the material with a special steel ball. The test result is given as a Brinell hardness number, which expresses the relationship between the diameter of the trace left by the ball on the surface and the load value.The Rockwell test is a test performed by applying a certain load to the surface of the material. The test result is determined by measuring the surface deformation caused by the applied load and is expressed as a Rockwell hardness number.The Vickers test is a test performed by applying a certain load to the surface of the material with a pyramid-shaped diamond tip. The test result is given as a Vickers hardness number that expresses the relationship between the size of the scar formed on the surface and the applied load.The Meyer test is a method used to measure the microhardness of the material. In this test, a hardening hammer creates impact induction by applying a specific load to the surface of the material. This induction causes a crater to form on the surface of the material. The size of the crater is related to the microhardness of the material.The Berkovich test is a

method used to measure the nanoscale hardness of the material. In this test, a triangular stiffener is pushed against the surface of the material by applying a certain load. This repulsion causes a mark to form on the surface of the material. The trace size is related to the nanoscale hardness of the material. Instrument trace testing (Martens hardness) is another method used to measure the hardness of the material. In this test, a hardening hammer or ball is dropped by applying a specific load to the surface of the material. This dropping causes a mark on the surface of the material. The trace size is related to the hardness of the material. The Knoop hardness test is another method used to measure the microhardness of the material. In this test, a diamond tip is pushed against the surface of the material by applying a certain load. This repulsion causes a mark to form on the surface of the material. The trace size is related to the microhardness of the material.

The results of these tests can help determine the material's mechanical properties, such as hardness, toughness, and strength.

The purpose of tensile tests is to determine the mechanical properties of a material and to classify it according to its mechanical behavior [17]. Because it gives information about the main mechanical properties of the materials; It is widely used in material selection for some engineering applications, checking whether the materials meet the desired quality standard, developing new materials and processes, comparing different materials, and determining material behavior in service conditions. In this context, many mechanical behaviors of materials such as yield, tensile and tensile strengths, elongation values and modulus of elasticity are obtained as a result of tensile tests [18].

With the fatigue phenomenon, the principles of which were introduced by Wöhler in the 1850s, it is known that serious mechanical defects will occur as a result of the materials being exposed to repetitive or changing stresses. Considering that almost 90% of mechanical defects in materials are caused by fatigue, the importance of fatigue can be better explained [19]. Moving parts such as shafts, connecting rods and gears are examples of parts subject to fatigue rupture.

Fatigue in materials develops in two stages and leads to fracture. These are the stages of crack formation and microscopic crack growth and reaching macroscopic size. Fatigue defects are affected by three main factors; a sufficiently high maximum tensile stress, the wide variation and fluctuation of the applied stress, and the effect of the applied stress on a sufficiently large number of repetitions. In addition, factors such as stress concentration, corrosion, temperature, overload, metallurgical structures, residual stresses and combined stresses, which tend to change the conditions for fatigue, can be counted [20].

2. CONCLUSION

AA2024 is an alloy consisting of a mixture of elements such as aluminum, copper, magnesium and manganese. In this alloy, magnesium, manganese and copper are the main alloying elements that increase the hardness of aluminum. The mechanical properties of the AA2024 alloy can be measured by hardness tests. Hardness tests are performed by applying a certain force to the surface of the material with a special hardness tool. This force leaves a mark on the surface of the material, and the size of this mark is used to measure the hardness of the material. Hardness tests give an idea about the durability and strength of the material. As a result of the hardness tests of the AA2024 alloy, it was observed that the mechanical properties of the alloy changed as the hardness of the alloy increased. Higher hardness values indicate that the alloy has a higher level of strength and hardness.

Table 2 *Brinell hardness values of AA2024 alloy*

Alloy	***Hardness Value (HB)***	***Resistance (MPa)***	***Elongation (%)***
AA2024	*80*	*185*	*10*
	95	*230*	*8*
	110	*275*	*6*
	125	*320*	*5*

As can be seen from this table, as the hardness value of the AA2024 alloy increases, its strength increases and the elongation value decreases. Therefore, the hardness value of the alloy should be optimized depending on the design and intended use.

The mechanical properties of the AA2024 alloy can also be determined by tensile tests. Tensile tests measure the tensile stress and elongation of the material. These tests provide comprehensive information about the durability and strength of the material. As a result of the tensile tests of the AA2024 alloy, the strength and hardness values increase as the tensile stress increases. However, as the tensile stress increases, the elongation rate decreases. For this reason, the optimum tensile stress should be determined by considering the material properties according to the design and usage purposes.

Table 3 *Typical mechanical properties of AA2024 alloy obtained as a result of tensile tests*

Alloy	***Stress Value (MPa)***	***Elongation Rate (%)***
AA2024	*280*	*18*
	310	*15*
	340	*12*
	370	*9*
	400	*6*

As can be seen from the table, the elongation rate decreases as the tensile stress of the AA2024 alloy increases. However, the material shows high strength and hardness even under tensile stress. Due to these properties, AA2024 alloy is widely used in areas such as aerospace, automotive and defense industries.

Table 4 *Typical mechanical properties of AA2024 alloy obtained as a result of fatigue tests*

Alloy	***Fatigue Strength (MPa)***	***Fatigue Life (number of revolutions)***
AA2024	*185*	*1.0 x 10^6*
	165	*1.0 x 10^7*
	150	*1.0 x 10^8*

The fatigue properties of the AA2024 alloy can be determined by fatigue tests. Fatigue tests measure the fatigue strength and fatigue life of the material by following the process of repeated loading and unloading of the material. These tests provide critical information about the durability and strength of the material. As a result of fatigue tests of AA2024 alloy, it shows high fatigue strength and

fatigue life. However, fatigue properties can vary depending on the material's surface quality, shape, size, and loading pattern. Also, AA2024 alloy may have lower fatigue strength than other alloys.

As can be seen from the table, AA2024 alloy has high fatigue strength and has a long fatigue life. However, fatigue strength may vary depending on the surface quality, shape, size and loading of the material. Therefore, the fatigue properties of materials such as the AA2024 alloy should be carefully studied according to their design and intended use.

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