Effect of Addition of Magnesium and Zinc to Obtain Optimal Mechanical Properties of Al-Mg-Zn Alloy

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Abstract. Many uses of aluminum led the researchers to develop this field by changing the target bullion to obtain alloys suitable for all specialties and possibilities. Adding some metals to aluminum leads to a change in properties, whether mechanical or physical, but in our research we target the mechanical properties, adding magnesium and zinc are in equal proportions (5%Mg-5%Zn, 10%Mg-10Zn). We offer this alloy to some tests such as hardness test, electrical conductivity test, compression test and Microstructure examination test. We compare the properties obtained with each other and with the basic properties of pure basic metal according to international standards.

Key word: Microstructure, Hardness, Electrical conductivity, Compression

1. Introduction

In our world we use Aluminum alloys in a lot of uses this is due to some of the properties of aluminum that qualify for industry such as ductility, easy configuration, light weight ... etc, but it also have some unwanted properties for an example: The ability to wear and react quickly to the formation of oxide. It is not used alone but is added to other minerals to improve its properties, it is widely used in many products in our everyday life in kitchenware, furniture, toys, deodorants, indigestion medicines, aircraft parts and missiles. Magnesium alloys have a magnesium capacity of mechanical and high working ability and also ability to weld and good appearance whether molded, polished or oxidized, they addition of zinc achieves this high alloy strength during the 20 to 30 days after casting and does not require any solution heat treatment to develop this alloy [1]. Presented an alloy from Mg - Zn - Ca - Ce and effects of volume fraction concentration Zn on the mechanical properties, so when Zn addition give best mechanical properties [2, 3]. Studied is effect of applied stress, plastic processing and degree of phase transformation on the influence in cases of incomplete martensitic transformation on the TiNi alloys [4,5]. Studied Mg alloys containing Mn and Zn under preheat temperature 200°, so performed was tests mechanical properties on alloys [6]. Presented study the effects of Cr addition...
of as – cast aluminum alloy for different volume fraction concentration give increase the toughness alloy [7]. Presented an alloy from Mg-3Zn-0.2Ca and effects of different volume fraction concentration Mn on the mechanical properties, so when Mn addition give best mechanical properties [8,9]. Studied are mechanical properties of the 2 mm plates of Mg-9Li-3Al-0.4Ce alloy and using X-ray diffraction, so, shown that the alloy includes two solid solutions of the Mg and Li. [10] Developed the alloy system Fe- Al – Cr – Ni composed of body-centered cubic and face-centered cubic, so adding small amounts of Molybdenum different concentration [11,12]. The prepared is new material aluminum alloy matrix with different volume fraction reinforcement alumina and carried out mechanical tests of tensile, hardness and toughness [13].The prepared Aluminum foam by using Al powder with NaCl and carried out compressed of different pressure while the NaCl dissolve in hot water at 70°C. [14]. The studied was the influence of the Al alloys the corrosion, sliding wear, and abrasive wear [15]. The purpose of this work is to obtain better of the mechanical properties of the Microstructure test, Hardness test; Electrical conductivity test and Compression test by addition some metals Magnesium and Zinc in equal proportions to Aluminum.

2. Experiment Tests

2.1. Alloys and their preparation

The alloys used are aluminum bases and have different ratios of magnesium and zinc. In order to prepare these alloys need to melting and casting metals in metal molds and then running the sample preparation. It was prepared in the following manner where the alloy weighed pieces of pure aluminum (wires 1-2 cm long) and calculated the corresponding quantities of the elements of Alloying to get the weight ratios required (10%,5%Zn) and (5%,10% Mg) as shown in table 1 it was taken using sensitive balance weights.

| Samples No. | Al% | Mg% | Zn% |
|-------------|-----|-----|-----|
| 1           | 90  | 5   | 5   |
| 2           | 80  | 10  | 10  |

Wires were used (1-2) cm and then aluminum was melted in the melting furnace under the temperature of 700°C, but before that was used temperature of 300°C to avoid rapid heating, after making sure that the melting was complete, magnesium strips and zinc powder were added by 10% zinc, 10% magnesium in one alloy, zinc% and% magnesium for the other alloy and move the mix from one period to another,The molten was then poured into a metal mold. We are obtained cast rods diameter (20.mm) and the length (135mm) . It has been running these bars by turning the machine and cut into several samples and different dimensions for the purpose of conducting the necessary tests.

2.2. Microstructure test

In order for this test to be done, we need to cut samples of the two particles with a Dimensions of 20 diameter and 10 height by use turning machine. These samples are subjected to grinding to remove the cracks or scratches which is on the surface by using grinding and polishing machine, where this device consists of an electric motor rotates the outer disk, which placed it made, grinding of(Magnesium, Zinc) with a degree of roughness sheets (180-220-400-800-1000-1200-2000), respectively, then was refined samples using covered turntable leaves refinement and using polishing paste Diamond (Aldaimund), then washing and drying process was conducted using a hot-air antenna dried between each grinding process or refine and Other. After that process were carried Backs structure using Manifesting Kilralve solution consists of (97% water + 3% nitric acid) for five seconds, and then using
the described in the optical microscope. When the grinding, polishing and sampling are completed, the samples are examined under the electronic microscope and see the difference in the microscopic structures of both, as in Figure 1 and Figure 2 Under 20 magnification.

![Figure 1. Microstructure of alloy (80% Al) X20](image1)

![Figure 2. Microstructure of alloy (90%) Al X20](image2)
2.3. Hardness Testing

Known as the hardness of the resistance to scratching and ductile deformation, also known as greatest resistance to deformation, the hardness is measured by load shedding and measure the depth or the impact of the load on the surface of the sample size by using Vickers hardness measurement scale. In this method of testing the use of stitches tool pyramid-shaped diamond intersect levels at an angle (136), as shown in figure 3, and that the value of the hardness is measured by the impact of the tool on the sample surface of the surface area of the account and can be calculated from the following equation:

\[ H_v = \frac{P}{d^2} \]  

Whereas :

- \( H_v \): the amount of Vickers hardness scale
- \( P \): amount load Applied (kg)
- \( L \): Qatari rate Length (mm)
- Amount load Applied (500g)

![Figure 3. Diameter Effect pyramidal](image)

It is characterized by accurately test readings costal square resulting impact which is a quadrangle and longer appropriate for measuring the hardness of thin materials as well as in the measurement of high Hardness. It is characterized by accurately test readings costal square resulting impact which is a quadrangle and longer appropriate for measuring the hardness of thin materials as well as in the measurement of high Hardness.
2.4. Electrical conductivity test

Electrical conductivity is a numerical term portability of the aqueous solution to carry an electric current, and this ability depends on the following:

- ions type
- the degree of concentration of ions
- Equal ions
- solution temperature

Most of the solutions of inorganic acids, bases and salts general have good conductivity. The symbol $\sigma$ is the property in the properties of any material represents its ability to transfer moving cargo from one place to another to forgive a substance for the passage of power where and expressed Georg Ohm in Ohm's law in the form magnetic reflect the amount of a modified version of the electric law as follows:

$$ J = \sigma E $$

(2)

$E$: the intensity of the electric field (volt / amp)

$J$: current density (mA / sq m)

The unit is the electrical conductivity (ohm per meter)) (In connector the electrical conductivity is inverted resistivity

$$ \rho = \frac{1}{\sigma} $$

(3)

As the metal resistance increased with increasing temperatures consequently, the electrical conductivity in metals increases as temperature decreases is expressed mathematically by the following law:

$$ \sigma_T = \frac{\sigma_T}{1 + \alpha(T - T_0)} $$

(4)

$\alpha$: is the thermal coefficient of the material.

2.5. Compression test

Compression strength is the amount of stress that is projected vertically on the axis, so the atoms will overlap and come together with each other, then the voltage will be stopped and the impact of the test on the sample. It is obtained compressive strength by using compression device universal (tensile testing machine), which consists of a fixed lower jaws decoder decoding moving upper. Test sample be cylindrical in shape, where the length of the amount of diameter 1.5 The sample was pressed quickly (1mm / s) Paints device stress–strain curve and be similar to the Figure 4 and Figure 5 A reds dot indicates a curved to the compressive strength of the material. Even in test compression region where there is a sin material is subject to Hooke's Law
\[ \sigma = E \epsilon \]  

E: coefficient of compressible

This linear region ends at the so-called point of submission, behave material above this point are Shape of plastically and will not return to its original length after the removal of load.

**Figure 4.** Stress-Strain curve of alloy (90\%) Al

**Figure 5.** Stress-Strain curve of alloy (80\%) Al
The actual area of the sample subject to strain change during the process of compression. In fact, the area load be Applied any function that

\[ A = f (F) \]  

Since stress is calculated by dividing the load Applied on the cross-sectional area at the beginning of the experiment Thus, the geometric strain will know that it:

\[ \varepsilon_g = \frac{L - L_o}{L_o} \]  

where:
- \( L \) = Length the current sample (m)
- \( L_o \) = Length the original sample (m)

And thus indicate compressive strain to the breaking point on the curve stress engineering strain Defined as follows:

\[ \sigma_e^* = \frac{F^*}{A_o} \]  

\[ \varepsilon_e^* = \frac{L^* - L_o}{L_o} \]

F * =applied load before breaking down completely.
L* = length of the sample before completely falling apart.

3. Results and Discussion

Hardness testing the results obtained by conducting a test of hardness after the addition of Magnesium and Zinc elements , so, the results before compression test and after compression test as shown in table 2 and table 3.

| Table 2. The relationship between the Vickers hardness and the weight ratio of component before compression test |
|---------------------------------------------------------------|
| values hardness(Hv) | Ratio element( Mg & Zn) % |
|----------------------|--------------------------|
| 215.75               | 5                        |
| 146.49               | 10                       |

| Table 3. The relationship between the Vickers hardness and the weight ratio of component after compression test. |
|---------------------------------------------------------------|
| values hardness(Hv) | Ratio element( Mg & Zn) % |
|----------------------|--------------------------|
| 184.68               | 5                        |
| 104.71               | 10                       |
Measuring the electrical conductivity to calculate the electrical conductivity of aluminum after the addition of Mg and Zn was used with a diameter samples (20mm) and the length (10mm). Where the device the user is measuring the electrical resistance and symbolized by the symbol (R), and through which we can calculate the resistivity and symbolized by the symbol \( \sigma \) through the following law:

\[
\rho = \frac{RA}{L}
\]

\[
A = \frac{\pi D^2}{4} \rightarrow A = 314.159 \text{mm}^2
\]

Measured electrical conductivity, or what is known susceptibility electrical conductivity \( k \) which is inverted resistivity as shown in table 4.

\[
\sigma = \frac{1}{\rho}
\]

**Table 4. Electrical conductivity of aluminum alloy -Mg –Zn**

| Mg & Zn\% | \( R(\Omega) \) | \( \rho(\Omega.m) \) | \( \sigma(\Omega^{-1}.\text{m}^{-1}) \) |
|----------|----------------|----------------|----------------------------------|
| 5        | 14.2*10^{-3}   | 435.955*10^{-6} | 2.293*10^{3}                     |
| 10       | 16.65*10^{-3}  | 747.228*10^{-6} | 1.338*10^{3}                     |

Compression test In this test were the following values are calculated for each sample (yield stress \( \sigma_y \), stress the first break \( \sigma_f \), elastic modulus \( E \) ) from figure 6 and figure 7 were obtained on these values from testing device where meted gives powers to the values of the sample and the amount of elongation occurring where Shift of power to the corresponding values of the stress as shown in table 5 it by using the following law:

\[
\sigma = \frac{F}{A}
\]

Elongation values transformation to the corresponding strain it by using the following law:

\[
\varepsilon = \frac{\Delta L}{L_0}
\]

**Table 5 Then draw a relationship between stress and strain values**

| Al\% | Speed(mm/min)) | \( L_f \) (mm) | \( D_0 \) (mm) | \( D_f \) (mm) | \( A_0 = \frac{\pi D_0^2}{4} \) (mm²) | \( A_f = \frac{\pi D_f^2}{4} \) (mm²) | First crack \( \sigma \) (Mpa) | \( \sigma_y \) (Mpa) | \( E \) (Gpa) |
|------|----------------|----------------|----------------|----------------|----------------------------------|----------------------------------|----------------|----------------|------------|
| 90   | 0.5            | 20.14          | 19.28          | 10.16          | 10.42                            | 81.07                            | 85.27          | 65.56          | 825        | 17.43      |
| 80   | 0.5            | 19.91          | 8.7            | 10.04          | 15.69                            | 79.169                           | 193.34         | 98.94          | 370        | 37.4       |
Stress-strain curve 90% Al

**Figure 6.** The relationship between stress scheme emotion of alloy (90% Al$_{5\%}$Mg$_{5\%}$Zn)

Stress-strain curve 80% Al

**Figure 7.** The relationship between stress scheme emotion of alloy (80% Al$_{10\%}$Mg$_{10\%}$Zn)
4. Conclusion

Microstructure test result the increase in addition of zinc and magnesium leads to a random increase in the arrangement of atoms and their spread, but in the case of aluminum, most metals are added to the grade on the crystalline limits of aluminum metal. Hardness Testing results obtained by conducting a test of hardness after the addition of Magnesium and Zinc elements reduce of hardness values. Test compression in this test were the following values are calculated for each sample (yield stress (σy), stress the first break (first fracture σ), elastic modulus (E)). Were obtained on these values through the use of charts resulting from public testing device where meted gives powers to the values of the sample and the amount of elongation occurring where Shift of power to the corresponding values of the stress.

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