

Improving of some Mechanical properties , Microstructure and Electrical Conductivity of Pure Aluminum by adding Zinc

Sundus Abbas Jasim

Babylon University / College of Materials Engineering/Metallurgy Department.

Sundus abbas 2012@yahoo.com

Abstract

In this research study the effect of addition of zinc on the mechanical properties (Hardness , yield strength , Ultimate stress) for pure aluminum and also microstructure , density , addition to the electrical conductivity , three alloys were prepared by change ratios add zinc (10% , 20% , 30%).

The results showed that increased proportion of zinc added to pure aluminum caused an increase in the yield stress and improving ratio reach to 84.86% and also an increase in ultimate stress and improving ratio reach to 78.58% at ratio(30 %) , and an increase in the hardness reach improving ratio to 43.45% at ratio (30 %) while the decrease in electrical conductivity to the value of $(0.703 \times 10^6 \Omega^{-1} \cdot m^{-1})$ and increase in the density and improving ratio reach to 13.814% when the ratio of zinc added to the pure aluminum increases , a change in microstructure and regular distribution of zinc on the boundary of crystalline for alloys, has also been noticed.

Keywords: Aluminum alloys, Zinc, Mechanical properties, Electrical conductivity.

الخلاصة:

تم في هذا البحث دراسة تأثير إضافة الخارصين على الخواص الميكانيكية (الصلادة، إجهاد الخضوع، أقصى إجهاد) للألومنيوم النقي وكذلك البنية المجهرية والكثافة بالإضافة إلى الموصلية الكهربائية .

تم تحضير ثلاث سبائك بتغير نسب إضافة الخارصين (10% , 20% , 30%) بينت النتائج ان زيادة نسب اضافة الخارصين الى الالمنيوم النقي يسبب زيادة اجهاد الخضوع ونسبة تحسن تصل الى 84.86% وكذلك زيادة اقصى اجهاد ونسبة تحسن تصل الى 78.58% عند النسبة 30% وزيادة في الصلادة تصل لنسبة التحسن الى 43.45% عند النسبة (30 %) بينما يحدث انخفاض في الموصلية الكهربائية الى قيمة $(0.703 \times 10^6 \Omega^{-1} \cdot m^{-1})$ وزيادة الكثافة ونسبة تحسن تصل الى 13.814% عند زيادة نسبة الخارصين المضافة . كما تم مشاهدة التغير بالبنية المجهرية والتوزيع المنتظم للزنك على الحدود البلورية للسبائك.

كلمات مفتاحية: سبائك الألومنيوم ، الخارصين ، الخواص الميكانيكية ، الموصلية الكهربائية.

1. Introduction

In recent year , aluminum and aluminum alloys are widely used in automotive industries. These are light weight (density of about 2.7g/cc), having good malleability and formability, high corrosion resistance and high electrical and thermal conductivity. High machinability and workability of aluminum alloys are prone to porosity due to gases dissolved during melting processes. However, in the engineering application pure aluminum and its alloys still have some problems such as relatively low strength, unstable mechanical properties. The microstructure can be modified and mechanical properties can be improved by alloying, cold working and heat treatment.

[Rana , *etal* , 2012] Aluminum alloys with a wide range of properties are used in engineering structures. Selecting the right alloy for a given application entails considerations of its tensile strength, density, ductility, formability, workability, weldability, and corrosion resistance. Aluminum alloys are used extensively in aircraft due to their high strength-to-weight ratio. On the other hand, pure aluminum metal is much too soft for such uses, and it does not have the high tensile strength that is needed for airplanes and helicopters. Thus various alloying elements are added to aluminum to enhance the mechanical properties of aluminum. [Nafsin & Rashed , 2013]

There are many research studies addition of alloying elements for a pure aluminum including:

[Isadare *et al*, 2013] have studied the effects of annealing and age hardening heat treatments on the microstructural morphology and mechanical properties of 7075 Al alloy. The material was cast in the form of round cylindrical rods inside green sand mould from where some samples were rapidly cooled by early knockout and others gradually cooled to room temperature. From the results obtained there is formation of microsegregations of $MgZn_2$ during gradual solidification which was not present during rapid cooling. It was also found out that age hardening and annealing heat treatment operation eliminated these microsegregations and improve mechanical properties of 7075 Al alloy.

[Khaleel & Bash, 2013] have studied the effect of Zinc addition to pure Aluminum to resist dry sliding wear had been studied using the pin-on-disc technique, to calculate the wear rate for pure Aluminum samples, and others with the addition of Zinc at different rates (1%, 3%, 5%), during sliding the test samples under dry sliding conditions on a disk of carbonic steel at different loads, variable slide speeds, and variable slide periods. The results showed that the wear rate decreases with increasing the Zinc proportion for the test samples. It has been noted that the increasing the applied vertical load leads to increasing the rate of wear and the rate of wear at 5% Zinc is less than the other rates. The results also showed that the rate of wear decreases with the increase of sliding speed for all the above added ratios.

[Ahmed, 2012] was studied the effect of adding Zinc to the pure Aluminum, The obtained results showed that increasing the percentages of adding Zinc to the pure Aluminum causes decreasing the thermal specifications (C_v , k , α). As for Zinc, its addition to pure Aluminum led to deterioration of the thermal properties during all ratios.

In this research, the zinc element is used to show its effects in an improving the pure aluminum.

The research aims to study the effect of adding different ratios of zinc on the mechanical properties (yield stress, ultimate stress, hardness), microstructure, density and electrical conductivity for pure aluminum because the importance of aluminum alloys in industrial fields.

2. Experimental Part

Experimental part include the process of preparation of materials used in the chemical composition of the alloy, process of melting, casting, operation, preparation of samples and tests.

2.1. Preparation of Alloys

The preparation of the alloys so that the weight of a pieces of pure aluminum (wires length (1-2) cm) and calculate the corresponding quantities of zinc element to get the weight ratio required (10%, 20%, 30%) Zn.

The used of ceramic pot for the purpose of setting the components of the alloys during the process of melting in electric furnace.

The melting process and casting as follows:-

1. Pure aluminum wires and cut into pieces (wires length (1-2) cm).
2. Aluminum pieces are used put in the melting pot and put in the melting furnace (Italian origin type MILAN-20122) for the smelting process after heated to temperature (700 °C) to ensure the total melting for the purpose of obtaining fusible empty from defects.
3. Zinc powder surrounded by foil of aluminum is added to molten aluminum and its moved well by tool made of graphite for the purpose of obtaining complete

homogeneity and then casting in a mold that has been heated to a temperature (300 ° C) before casting process in order to avoid sudden solidification and non-homogenized for molten in the mold.

4. Casting process was conducted three times to aluminum – zinc alloy and different ratios of zinc .
5. Sample cast of diameter (22.6 mm) and length (80 mm) were obtained.



Figure (1) show melting furnace.

2.2. Samples preparation

The samples were run by turning machine and cutting into new samples of different sizes for the purpose of making the necessary tests which began the process of grinding using paper of silicon carbide with grades 180, 400, 600, 800, 1200, 1500, 2000 after the polishing process was conducted using a polishing machine (Model (MP- 2B), Chinese origin) and used in the process alumina powder and water, it was also conducted washing and drying process with hot air between each operation of polishing and other.

2.3. X-Ray Diffraction Test

X-ray diffraction was used to study the phases of the Aluminum – Zinc alloys with measuring condition as below.

Target: Cu, wave length = 1.5406 \AA , speed (6.000 deg / min)

2.4. Microstructure Test

It has been using an optical microscope type (union – 3154 ,Model (optical-1101579), Chinese origin) magnification (200X).for the purpose of examining the microstructure of the alloys.

After grinding and polishing using mechanical polishing device type (HERGON) , images microstructure after casting process , use of the etching solution (Keller' s Reagent) chemical composition as following:

(25%HF + 10% HCL+ 15% HNO₃ +50% H₂O) .It was the time of the show ranges between (10-20)s. [Yasir , 2014]

2.5. Compression Test

Compressive strength is the value of stress compression which reach it sample when the total collapse (usually cylindrical sample will shorten and spread sideshow diagonally).

Since the atoms in solid bodies always trying to find for itself balanced position between atoms, show the forces inside the material inversion process, these forces are shown in the form of strain.

In this test the value are calculated for each sample (ultimate stress, yield stress)

It has been getting these values through the use of schemes resulting from.(Universal Testing ,Model (WAW- 200) Chinese origin) where gives the values of forces applied on the sample and the amount of elongation.

Forces turned to the corresponding for values of stress by using the following law:

$$\sigma = \frac{F}{A_0} \quad \text{..... (1)}$$

Where as

σ stress

F force

A_0 original area

Elongation values turned to the corresponding for values of strain by using the following law:

$$\epsilon = \frac{\Delta L}{L_0} \quad \text{..... (2)}$$

ϵ strain.

ΔL elongation.

L_0 original length.

After that draw a relationship between stress and strain values.

Test sample cylindrical where length (1.5) amount of diameter and it was sample pressure quickly (1mm/s).

2.6. Hardness Test

Hardness test is an indicator of changes in the mechanical properties for samples, where measuring the hardness of the samples after the process of casting.

The method used to measure the hardness is a Vickers method (Model (HVS- 1000), Chinese origin) and the amount of load is (15.63) kg according to the following formula: [Nayak & Karthik ,2011]

$$VHN = \frac{1.854 P}{D^2} \quad \text{..... (3)}$$

Where as

HVNVickers hardness.

P applying load (kgf).

D average length of diagonals (mm).

2.7. Electrical Conductivity Test

After the addition of zinc to pure aluminum calculates the electrical conductivity of the alloys, it was used samples (22.6) mm diameter and (5.5) mm length, where the user device measure the electrical resistance is (ATS 12 Precision Ohmmeter, Chinese origin)) through which we can calculate resistivity through the following law [Miller , *etal*, 1988]:

$$\rho_{Ele} = \frac{R.A}{L} \quad \text{..... (4)}$$

Where as

ρ_{Ele} resistivity.

R resistance.

L sample length.

Electrical conductivity (σ_{Ele}) is measured by reversed resistivity.

$$\sigma_{Ele} = \frac{1}{\rho_{Ele}} \quad \text{..... (5)}$$

2.8. Density Test

Density described physical of objects to express the relationship between unit volume and unit mass for material or object. If increased density increased mass per unit volume.

To calculate the density after the addition of zinc element for pure aluminum. The samples of alloy were diameter (22.6) mm and length (5.5) mm. we weight samples and measure the volume then calculate the density by the following law:

$$\rho = \frac{m}{V} \quad \text{..... (6)}$$

Where as

ρ density.

m mass.

V volume.

If ($V = A \times L$)

$$V = \frac{\pi}{4} d^2 \times L$$

3. Results and Discussion

3.1. X- Ray Diffraction Test

Figure (2) represent the diffraction of x-ray of pure aluminum , shows the peaks of pure aluminum and figure (3) illustrated x-ray diffraction for samples of aluminum – zinc alloys and shows the peak of aluminum and zinc in alloys .

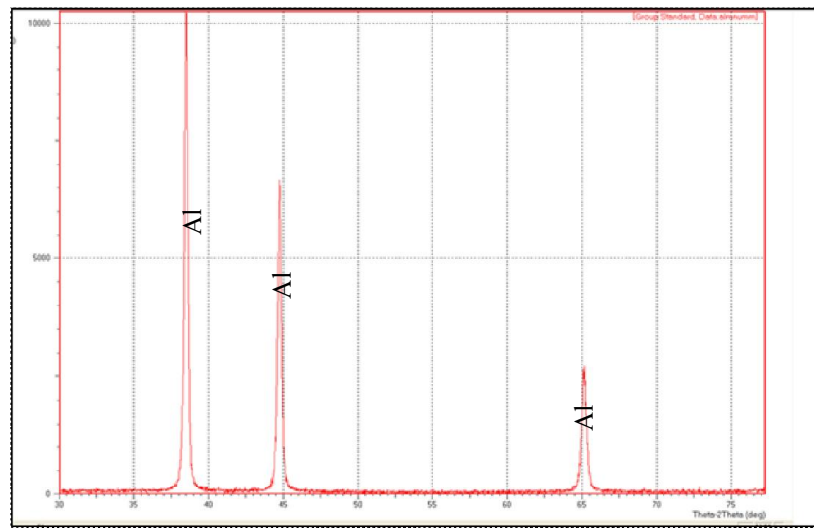


Figure (2) represent X- ray diffraction of pure aluminum.

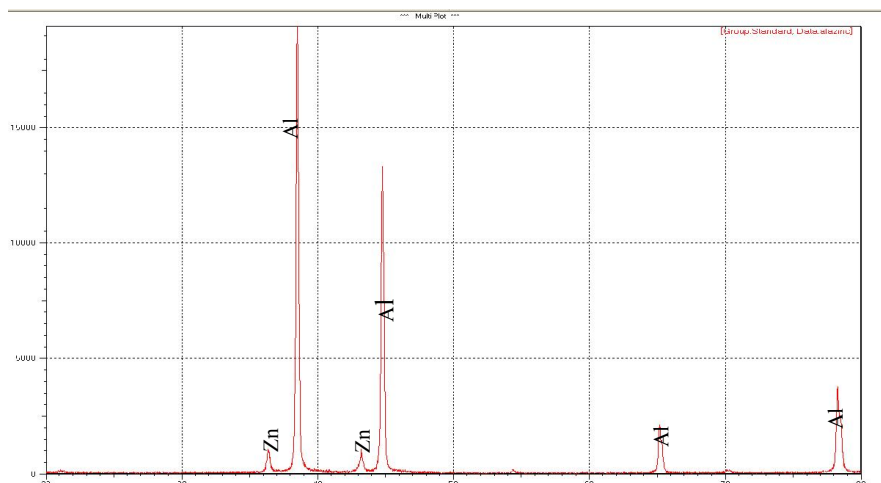


Figure (3) represent the diffraction of x-ray of Al- 10% Zn alloy

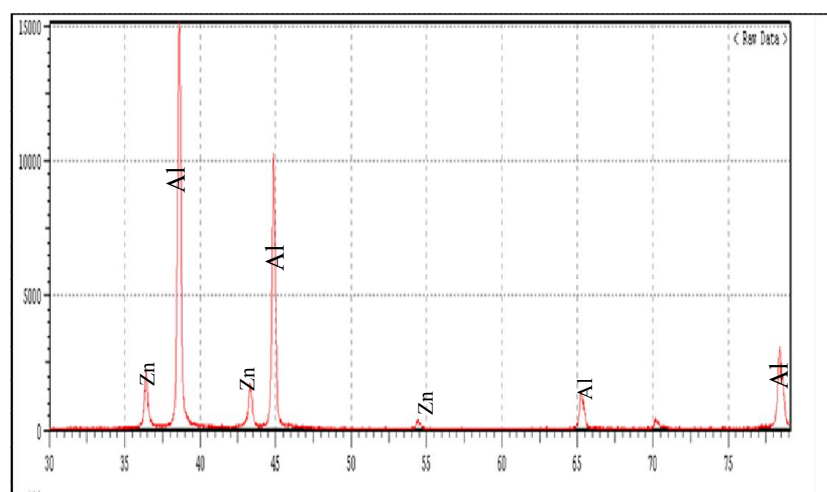


Figure (4) represent the diffraction of x-ray of Al- 20% Zn alloy.

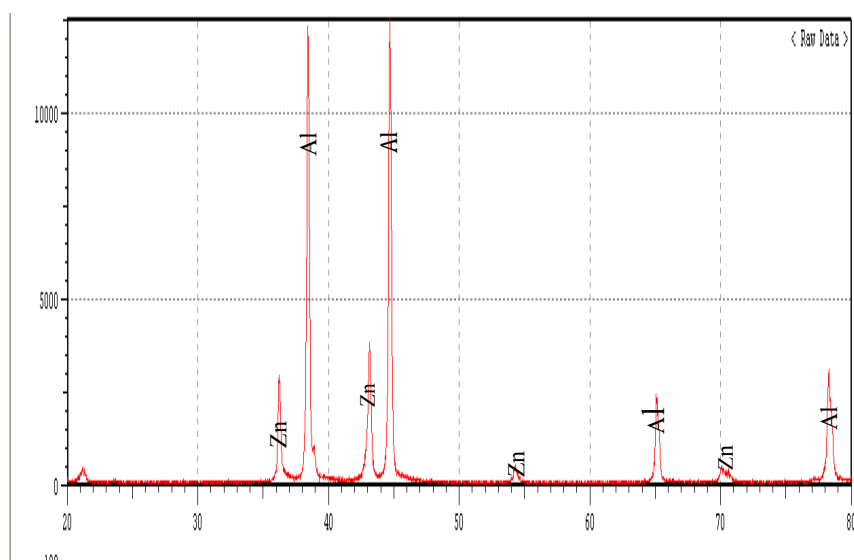


Figure (5) represent the diffraction of x-ray of Al- 30% Zn alloy.

3.2. Microstructure Testing

It were imaged the microstructure of the samples cast as well as the pure aluminum and examination of the microstructure of the alloys . In general , we note that the green area , indicate the aluminum element, while the black areas indicate the zinc element where we note that this area increase with the proportion of zinc element and increased deposition of zinc element on the crystalline boundaries of alloy. The figures (6), (7), (8) & (9) show microstructure for pure aluminum, alloys and percentages of zinc additive.

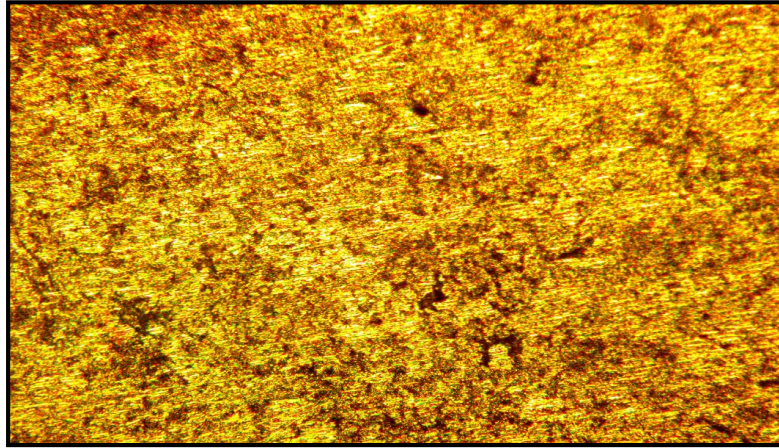


Figure (6) show microstructure for pure aluminum (200X).

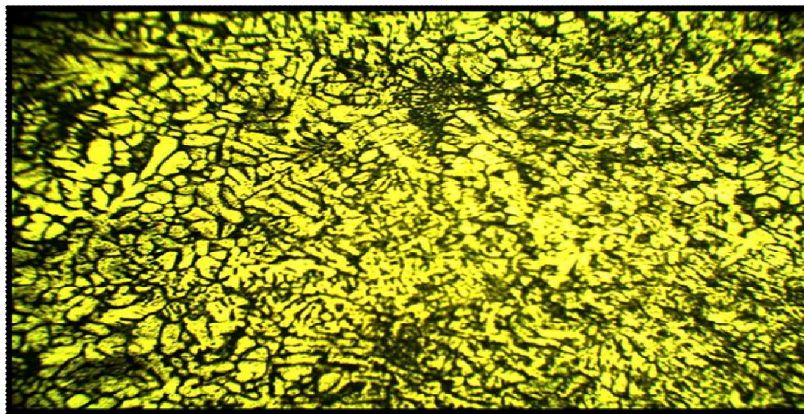


Figure (7) show microstructure for (Al – 10%Zn) alloy (200X).

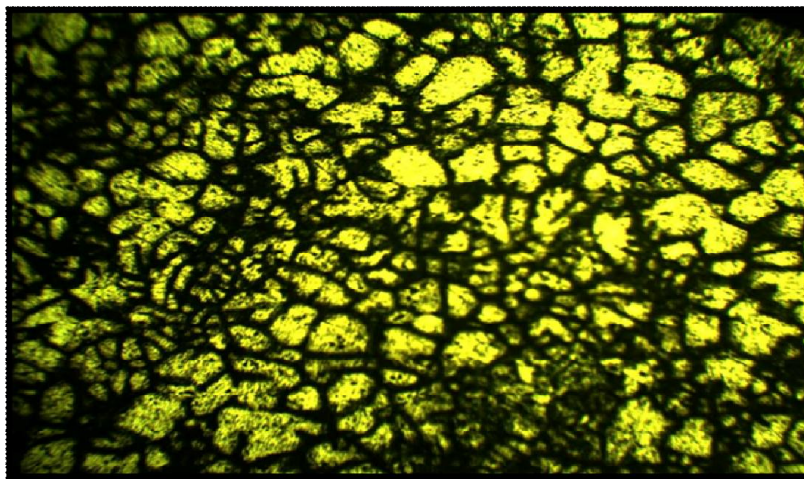


Figure (8) show microstructure for (Al –20% Zn) alloy (200X).

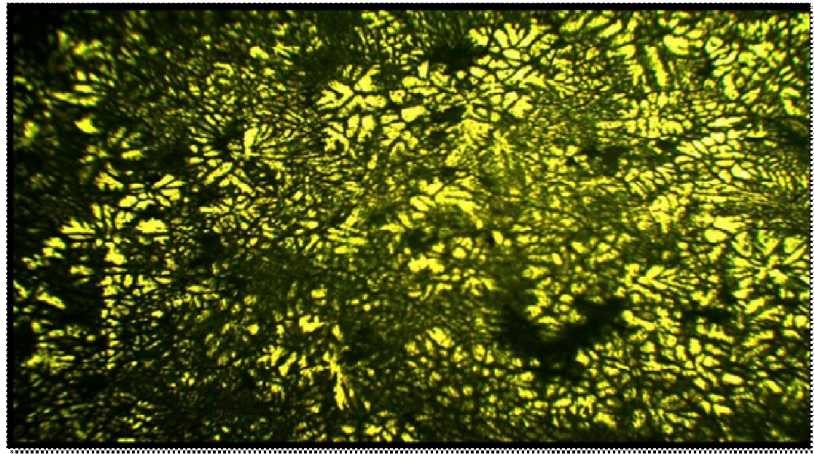


Figure (9) show microstructure for (Al – 30%Zn) alloy (200X).

3.3. Compression Test

The relationship between stress and strain has been observed through the schema increasing the value of the yield stress with increase the proportion of zinc and improving ratio reach to 84.86% and so ultimate stress the improving ratio reach to 78.56% at ratio 30% compared with other ratios and the reason is crystals of zinc work as a barrier movement of dislocations and thus will increase both (σ_y) and (σ_u), since the zinc will be on the crystalline boundaries. The table (1) shows yield stress and ultimate stress values for pure aluminum, percentages of additive and improving ratio.

Table (1) shows yield stress and ultimate stress values for pure aluminum, percentages of additive and improving ratio.

Zn wt. %	σ_y (Mpa)	Improving ratio%	σ_u (Mpa)	Improving ratio%
0	89.126	0	190.985	0
10	222.81	59.99	493.39	61.49
20	331.04	73.07	713.06	75.705
30	588.87	84.86	891.26	78.58

3.4 . Hardness Testing

Vickers hardness was measured for Aluminum- zinc alloy after the addition of different ratios of zinc to pure Aluminum, it has been observed that the Aluminum – zinc alloy possessed a higher hardness and improving ratio reach to 43.45% when adding 30% zinc compared with other ratio, whose improving ratio 40.12% when the ratio 20% and 8.57 % when the ratio 10%. This means that increasing zinc element increases the value of hardness of the alloy and the reason for this is to hardening phase of the element zinc, which is deposited on a crystalline boundaries. The table (2) shows the hardness values for pure aluminum, percentages of zinc additive and improving ratio.

Table (2) shows the hardness values, percentages of zinc additive and improving ratio.

Zn wt. %	Hardness values(HV)	Improving ratio%
0	48.17	0
10	52.3	8.57
20	67.5	40.12
30	69.1	43.45

3.5. Electrical Conductivity Test

Note that the addition of zinc element to pure aluminum will be reduced electrical conductivity, the reason for this is to enter the zinc element as a distortion and impurity element of each of the free electrons and crystalline network. [Alean & Banbury, 1994]

The table(3) shows the resistance, resistivity and electrical conductivity values for pure aluminum and percentages of additive

Table (3) shows the resistance, resistivity and electrical conductivity values for pure aluminum and percentages of additive.

Zn wt.%	R(Ω)	$\rho(\Omega.m)$	$\sigma(\Omega^{-1}.m^{-1})$
0	$0.0044*10^{-3}$	$0.203 *10^{-6}$	$4.92 *10^6$
10	$1.35*10^{-5}$	$0.984*10^{-6}$	$1.015*10^6$
20	$1.70*10^{-5}$	$1.239*10^{-6}$	$0.807*10^6$
30	$1.95*10^{-5}$	$1.422*10^{-6}$	$0.703*10^6$

3.6. Density Test

Note that the addition of zinc element to pure aluminum, it leads to increase density of the alloy and improving ratio reach to 13.814 % at 30% compared with other ratios, whose improving ratio reach to 8.518% at 20% and 5.814% when the ratio is 10%, because zinc is more density than aluminum, this increase with increases the proportion of the added zinc. The density of aluminum is $(2.7)g/cm^3$ while the density of zinc is $(7.14) g/cm^3$. The table (4) shows the density values and ratio of zinc additive.

Table (4) shows the density values and ratio of zinc additive

Zn wt.%	$\rho(g/cm^3)$	Improving ratio%
0	2.7	0
10	2.857	5.814
20	2.930	8.518
30	3.073	13.814

Conclusions:

1. Properties of aluminum drastically changed when certain elements of casting are added. The hardness of aluminum increases when zinc element is added and improving ratio reach to 43.45 %.
2. The addition of zinc to pure aluminum; it leads to increased density for being more density than pure aluminum and improving ratio reach to 13.814%.
3. The pure aluminum has high electrical conductivity; the addition of any element to pure aluminum leads to reduce electrical conductivity.
4. Microstructure of the alloy was observed regular distribution for the deposition of zinc element on the crystalline boundary for alloy (Al – Zn).
5. The addition of zinc element to pure aluminum leads to increase yield stress and improving ratio reach to 84.86 % also increased ultimate stress reaches improving ratio to 78.58%.

5. References:

- Ahmed M. S., 2012, study the effect of magnesium and zinc addition on thermal properties of pure aluminum, Tikrit Journal for engineering sciences, Vol .19, No.4, (74 – 84).
- Alean R. C., Banbury, 1994, physical properties, characteristics and alloys, European Aluminium Association.

- Cobden R. ,Alean and Banbury , 1994 , physical properties , characteristics and alloys , European Aluminium Association.
- Isadare A.D. , Aremo B. , Adeoye M.O. , Olawale O.J.and Shittu M. D. , 2013 , Effect of Heat Treatment on some Mechanical properties of 7075 Aluminium Alloy , Materials Research , 6(1) : 190-194.
- Khaleed J. and Bash A. M. , 2013 ,Study the effect of Zinc addition on dry sliding wear rate of pure aluminum , Academic Research International , Vol.4, No.5, ISSU: 2223-9944.
- Miller R .L . , Bradford W .L . and Peters N . E . , 1988 , specific conductance : theoretical considerations and application to analytical quality control, U.S.Geological Survey Water- Supply Paper 2311.
- Nafsin N. , Rashed H. M .M .A., 2013 , Effect of copper and magnesium on microstructure and hardness of Al- Cu – Mg alloys , International Journal of engineering and Advanced Technology , vol 2 , Issue 5 , ISSN:2249 – 8958.
- Nayak S. , Karthik A.,2011, Synthesis of Al-Si Alloys and study of their Mechanical properties, Bachelor Technology , INDIA.
- Rana R.S., purohit R. , and Spas ,2012 , reviews on the influences of alloying elements on the microstructure and mechanical properties of aluminum alloys and aluminum alloy composites , International Journal of scientific and research publications , vol 2 , ISSU6, issue :2250-3153.
- Yasir .M. A. , 2014 ,Effect of copper addition on the microstructure and mechanical properties of Al-Si alloy , Al –Qudisiya Journal for Engineering Sciences , Vol.7 , No.4.