*International Journal on Emerging Technologies* **3**(1): 137-140(2012)

**ISSN No. (Print) : 0975-8364**
**ISSN No. (Online) : 2249-3255**

# Effect of Magnesium Content on the Mechanical Properties of Al-Zn-Mg Alloys

***Lucky Agrawal*, Rakesh Yadav* and Abhishek Sexena*****

**Department of Mechanical Engineering, Al-Falah School of Engineering and Technology, Faridabad, Haryana*
***Hi-Tech Institute of Engineering and Technology, Ghaziabad, (U.P.)*

*(Recieved 15 March, 2012 Accepted 10 April, 2012)*

**ABSTRACT : Nowadays various kinds of aluminium alloys are utilized widely in different types of manufacturing industries, like automobile, aerospace etc. It is very difficult to find any other metallic element that can be used in so many ways. Aluminium can be used in its pure form or in the form of an alloy by combining it with a variety of other elements like Copper, Magnesium, Manganese, Silicon, and Zinc etc. Each element imparts different characteristics to the alloy and their composition has a varying effect on the mechanical properties of the alloy [1].**

**This project is aimed at studying the effect of varying the composition of Magnesium on the mechanical properties like strength and hardness in an Aluminium-Zinc-Magnesium alloy. Sand casting was used for the purpose of the project and testing was done on the samples for determining the resultant mechanical properties.**

**Keyword :** Alloy, Al, Zn, Mg, Tensile Strength, Elongation, Hardness.

## I. INTRODUCTION

Aluminium alloys are used in advanced applications because of their combination of high strength, low density, durability, machinability, availability and relatively lower cost as compared to other competing materials.

However, the properties of commercial aluminium alloys depend on the amount of elements like magnesium, copper, silicon, zinc and other alloying elements present in them. A variation in the composition of these elements has a significant impact on the mechanical properties of the resultant alloy. The properties are also influenced by the manufacturing techniques and heat treatment procedures employed [2].

In this project, an effort is made to study the effect of variation of composition of Magnesium in an Aluminium-Zinc-Magnesium alloy. The process used for preparing the specimens was casting which is a widely used manufacturing process due to its ability to produce complex shapes and relative economics as compared to other manufacturing processes.

The specimens were prepared using Sand Casting for different composition of magnesium in the Al-Zn-Mg alloy in order to study the effect of Magnesium on the mechanical properties like hardness and tensile strength of the resultant alloy having about 4% Zinc by weight.

## II. MATERIAL AND METHODOLOGY

Commercially available Aluminium, Zinc and Magnesium were taken for the present study. Alloy having 4% Zinc by weight was prepared and composition of Magnesium by weight was varied.

A coal fired induction furnace with graphite crucible was used for melting the metals. Cylindrical specimens were prepared using Sand Casting for different compositions of alloying elements. The specimens were having cylindrical shape with a diameter of about 25 mm, length of about 180 mm and about 250 grams in weight.

Each melt was held at above 700°C for about 10 minutes so as to attain a homogeneous composition. After pouring, the resultant samples were allowed to solidify and cooled in normal room temperature.

The cast samples were machined to tensile configuration having the following dimensions:

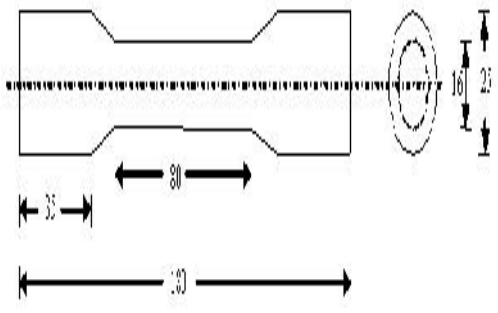


Fig. 1. Specimen.

Tensile testing was done on a Universal Testing Machine. Brinell Hardness was measured using Brinell Hardness tester.

## III. RESULTS AND DISCUSSION

### A. Compositional Analysis

The following table shows the weight percentage of different elements present in the prepared specimens.

**Table 1: Weight percentage of different elements present in the Al-Zn-Mg specimens.**

| *Element* | *Sample 1* | *Sample 2* | *Sample 3* | *Sample 4* | *Sample 5* | *Sample 6* |
|---|---|---|---|---|---|---|
| Al | 99.19% | 95.88% | 95.56% | 92.73% | 94.60% | 93.59% |
| Zn | 0.00% | 3.64% | 3.27% | 3.63% | 3.32% | 3.63% |
| Mg | 0.00% | 0.00% | 0.78% | 1.06% | 1.66% | 1.81% |
| Si | 0.010% | 0.011% | 0.013% | 0.012% | 0.012% | 0.010% |
| Cu | 0.021% | 0.027% | 0.023% | 0.031% | 0.026% | 0.031% |
| Mn | 0.14% | 0.16% | 0.13% | 1.76% | 0.26% | 0.56% |
| Fe | 0.61% | 0.26% | 0.21% | 0.75% | 0.11% | 0.34% |
| Ni | 0.01% | 0.01% | 0.00% | 0.01% | 0.00% | 0.01% |

The target weight percentage of Zinc in Sample 2, sample 3, sample 4, sample 5 and sample 6 was 4%. The actual percentage was 3.64%, 3.27%, 3.63%, 3.32% and 3.63% respectively which can also be considered as acceptable as it will not have a significant impact on the nature of the current study.

The target weight percentage of Magnesium in sample 3, sample 4, sample 5 and sample 6 was 0.5%, 1.0%, 1.5% and 2.0% respectively. However, as can be seen from the above table, the actual weight percentage was 0.78%, 1.06%, 1.66% and 1.81% respectively. As the purpose of this project is to study the effect of increasing percentage of Magnesium in Al-Zn-Mg alloy, these values can also be taken as acceptable.

It can be seen that the percentage of Manganese is also varying a lot across the samples, especially in the samples which were cast later. This is a significant variation given the fact that no Manganese was added during casting. However, this may be due to the Manganese already present in the Aluminium taken for the study and separation of the same during melting in the furnace.

As Manganese being a heavier element than Aluminium, it might be possible that while melting the Aluminium alloy in the furnace, Manganese particles move to the lower end of the crucible rather than being homogeneously mixed with Aluminium. Hence, in the early castings, *i.e.* Sample 1, Sample 2 and Sample 3, a relatively lower concentration of Manganese was present whereas in the later castings, *i.e.* Sample 4, Sample 5 and Sample 6, a higher percentage of Manganese was there. Pouring temperature, height, stirring and other factors also contributed to the resultant amount of Manganese present in the Aluminium alloy.

A smaller variation in other materials was also observed in the samples which can also be attributed to separation of particles while melting and difference in densities of different metals.

### B. Tensile Testing

Elongation and tensile testing was carried out using the Universal Testing Machine. Results of tensile and elongation testing is as under:

**Table 2 : Elongation and Tensile Testing Results.**

| *Specimen No.* | *Mg (%)* | *Zn (%)* | *Mn (%)* | *UTS (MP)* | *El (%)* |
|---|---|---|---|---|---|
| 1. | 0.00% | 0.00% | 0.14% | 198 | 1.95% |
| 2. | 0.00% | 3.64% | 0.16% | 202 | 1.80% |
| 3. | 0.78% | 3.27% | 0.13% | 205 | 2.20% |
| 4. | 1.06% | 3.63% | 1.76% | 204 | 1.60% |
| 5. | 1.66% | 3.32% | 0.26% | 207 | 2.05% |
| 6. | 1.81% | 3.63% | 0.56% | 209 | 1.70% |

ULTIMATE TENSILE STRENGTH

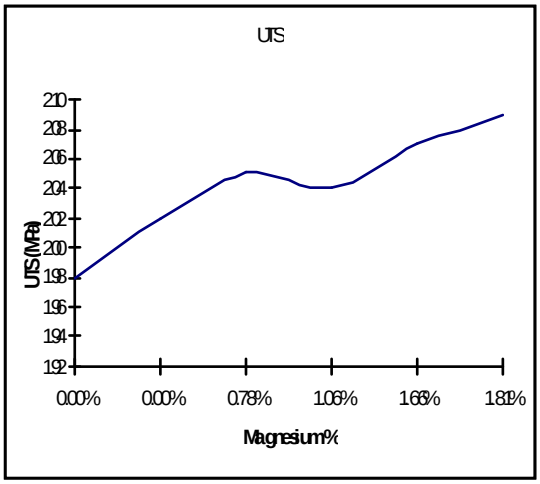


Fig. 2. Curve showing variation of UTS with percentage of Magnesium.

From the above table, it can be seen that addition of both Zinc and Magnesium in the Aluminium alloy increases the UTS of the resultant alloy. The UTS of sample 1 was 198 MPa which was pure Aluminium alloy.

As about 4% Zinc was added in sample 2, UTS increases to 202 MPa. With the addition of Magnesium in sample 3, the UTS further increases to 205 MPa.

As Magnesium was further increased in sample 4, the expected UTS would have been higher than that of sample 3. However, the actual UTS number was found to be 204 MPa. This could be due to separation of metals during melting and Manganese being heavier than Aluminium, the particles of Manganese moved to the bottom of the crucible.

As a result, Magnesium content was lower in the earlier cast samples whereas there was an increase in Manganese content in samples which were case later. As we see in sample 4, the UTS number is lower at 204 MPa.

The higher content of Manganese along with the presence of Zinc, Magnesium and other alloying elements might have had a negative impact on the tensile strength of the resultant alloy.

In sample 5, as Magnesium was further increased along-with a decrease in the Manganese content, UTS increases. In sample 6, the addition of Magnesium further increased the UTS.

ELONGATION

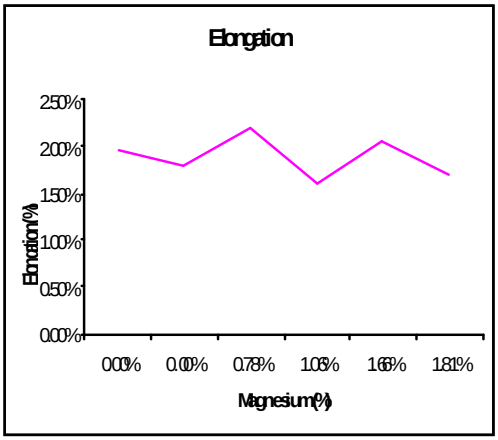


Fig. 3. Curve showing variation of Elongation with percentage of Magnesium.

As evident from above, Magnesium generally doesn't have much impact on the elongation of Aluminium Alloys. However, the presence of Manganese does have a significant impact on the elongation properties of the alloy. A higher Manganese content generally decreases the elongation characteristics of Aluminium alloys. This is also evident from the above results, as sample 4 which is having a higher Manganese content, is showing lower elongation as compared to previously cast samples.

The macro-hardness testing was carried out using Brinell Hardness testing machine. Results of hardness testing are as under:

**Table 3 : Hardness Test Results.**

| *Specimen No.* | *Mg %* | *Zn %* | *Mn %* | *Hardness (HB)* |
|---|---|---|---|---|
| 1. | 0.00% | 0.00% | 0.14% | 38 |
| 2. | 0.00% | 3.64% | 0.16% | 39 |
| 3. | 0.78% | 3.27% | 0.13% | 35 |
| 4. | 1.06% | 3.63% | 1.76% | 37 |
| 5. | 1.66% | 3.32% | 0.26% | 30 |
| 6. | 1.81% | 3.63% | 0.56% | 35 |

The below figure shows the variation of hardness (brinell) with variation of Magnesium in the Aluminium - Zinc alloys.

HARDNESS

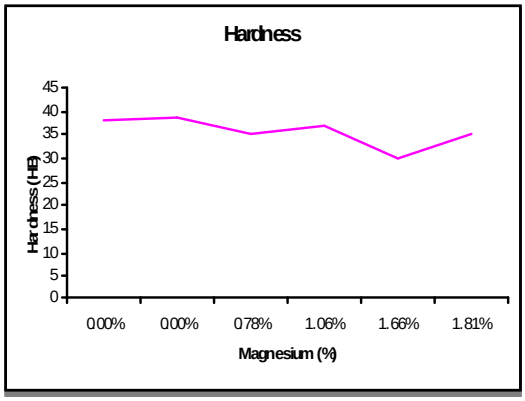


Fig. 4. Hardness vs Magnesium %.

As can be seen from the above, hardness of the alloy increases when Zinc was added to the alloy. With addition of Magnesium in the Al-Zn alloy, there was a slight decrease in the hardness, though the difference was not significant. However, in the fourth sample, hardness of the resultant alloy increases with further addition of Magnesium. This may be due to the increased amount of Manganese present in the alloy. There was a decrease in Hardness as more Magnesium was added along-with decrease in Manganese content. However, in sample 6 wherein Magnesium content was highest, hardness increases from the previous sample. This could again be due to the increased content of Manganese as compared to the previous sample.

## IV. CONCLUSION

(*i*) The compositions of the resultant alloys were varying across different samples especially with respect to Manganese content. This was due to the fact that during melting, the elements got separated and heavier metals move to the lower end of the crucible. As a result, the content of these metals was lower in castings done earlier.

(*ii*) The tensile strength of the resultant alloys increased with the addition of Zinc.

(*iii*) Magnesium also has a positive impact on the tensile strength of the alloy.

(*iv*) The presence of higher amount of Manganese in the Aluminium-Magnesium alloy had a negative impact on the tensile strength.

(*v*) Magnesium doesn't have much impact on the total elongation of the aluminium alloy. However, a higher content of Manganese decreases the total elongation of the alloy.

(*vi*) Hardness increased with addition of Zinc.

(*vii*) With an increase in Magnesium content, there was a slight decrease in hardness.

(*viii*) A higher content of Manganese resulted in increased hardness of the alloy.

(*ix*) Mechanical properties of Aluminium alloys depend not only on the content of alloying elements, but also on their relative chemistries with each other.

## REFERENCES

[1] Vadim S Zolotorevsky, Nikolai A Belov, Michael V Glazoff, "Casting Aluminum Alloys", Moscow, Pittsburgh, (2007).

[2] Wasiu Ajibola Ayoola*, Samson Oluropo Adeosun, Olujide Samuel Sanni, Akinlabi Oyetunji, "Effect Of Casting Mould On Mechanical Properties Of 6063 Aluminum Alloy", *Journal of Engineering Science and Technology* Vol. **7**, No. 1 (2012) 89 - 96, School of Engineering, Taylor's University.

[3] John Gilbert Kaufman, Introduction to Aluminium Alloys and Tempers, ASM International, (2000).

[4] John Gilbert Kaufman, Elwin L Rooy, Aluminium Alloy Castings: Properties, Processes, and Applications, American Foundry Society, *ASM International*, (2004).

[5] Joseph R Davis, Aluminium and Aluminium Alloys, *ASM International*, (1993).

[6] D. Apelian, Aluminum Cast Alloys: Enabling Tools for Improved Performance, North American Die Casting Association, (2009).

[7] S.O. Adeosun, S.A. Balogun, L.O. Osoba, W.A. Ayoola and A.M. Oladoye, "Effect of Cu and Zn Addition on the Mechanical Properties of Structural Aluminum Alloy", *Journal of Modern Manufacturing Technology*, **3**(1) January-June (2011); pp. 103-110.