Review of the Effects of Magnesium in Aluminium Alloys

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***Abstract*—**It is evident that the microstructure of pure materials can be varied by alloying elements. Magnesium plays an important role in defining the characteristics and properties of materials when it is added as an alloying element. This paper focuses on the various effects of magnesium in an aluminium alloy; emphasis is laid on the effects of magnesium on the microstructure and mechanical properties of aluminium. The paper would give the cumulated effects of magnesium under various conditions in the aluminium alloy.

***Keywords*—**Aluminium Alloy; Casting; Magnesium; Magnesium Powder; Melting.

***Abbreviations*—**Inductively Coupled Plasma - Optical Emission Spectrometry (ICP-OES).

I. INTRODUCTION

ALUMINIUM is the most found metal in earth, and it is the second most used metal. Nearly 8% of earth's crust is made up of aluminium. Aluminium is ductile and can be readily cast and machined. Aluminum is soft, lightweight, fire-proof and heat-resistant, easy to work into new shapes, and able to conduct electricity.

Magnesium is a chemical element with symbol Mg and atomic number 12. It is a shiny gray solid which bears a close physical resemblance to the other five elements in the second column (group 2, or alkaline earth metals) of the periodic table: all group 2 elements have the same electron configuration in the outer electron shell and a similar crystal structure [KarNovaković et al., 1; Gubicza et al., 4].

The melting point is 6500C. It has a white appearance. More than half of magnesium produced in this country is used in powder and ingot form for alloying with aluminum. About 30% is used for chemical processes and other nonstructural applications. Magnesium has great effect on the mechanical properties when used as alloying element with other group of metal of the same properties. Magnesium does show an advantage over other metal system in weight [Yaro & Aigbodion, 12].

Magnesium increases the strength and hardness of the alloys, but especially in castings, this is accompanied by a decrease in ductility and impact resistance. Standard industrial aluminium-copper alloys solidify with the formation of a dendrite structure, however, a tendency to form with a globular structure at higher copper contents was reported.

II. METHODOLOGIES FOLLOWED

2.1. Preparation

Aluminium Material

The material is either brought from the shop as per dimensions or it is bought and cut to dimensions. It is mainly obtained as an extruded component. Niyas Salim & Kumar [3] cleaned the aluminium ingots using acetone to make it free from moisture.

In the research by Salihu & AliyuIsah [10] they have not mentioned about the type of Al-Cu-Mg alloy or the material composition before conducting the experiment, while the other material was a 99.9% pure aluminium metal.

Bansal et al., [2] also did not mention about the material composition of the Al-Cu-Mg alloy.

Magnesium Powder

The magnesium to be added to the aluminium for testing the properties mostly is provided in the form of powder, that is finely ground so that a proper mixing can occur.

DIE

It is a permanent cylindrical die of diameter 25 mm with 200 mm long Die is to be preheated to 185^0C, Salihu & AliyuIsah [10] made this type of die. The preheating can be done in an industrial owen .

2.2. Melting

The compositions were melted in an electrical resistance furnace, using graphite crucible by Salihu & AliyuIsah [10] the temperature is usually set to a point where the aluminum starts to melt, care should be take that there is no loss of material in the form of vapour. The exact temperature to which the aluminium was heated is not known. The molten metal was poured into permanent cylindrical die of diameter 25 mm with 200 mm long.

2.3. Casting

The molten metal is poured into the cylindrical die and is held there for a certain amount of time to cool down. The authors did not mention about the type of cooling that had been performed on the material. The die is slowly removed and the cylindrical component is obtained.

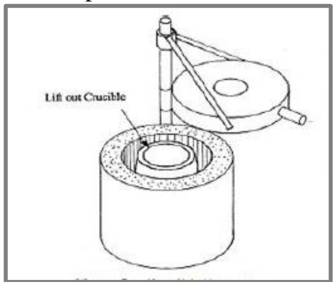

Figure 1: Schematic View of Furnace

Figure 2: Graphite Crucible

Table 1: Material Composition [Adeyemi et al., 6]

SPECIMEN	Cu	Mg	Al	Zn
1	88%(440g)	0%(20g)	10%(50g)	2%(10g)
2	87%(435g)	1%(20g)	10%(50g)	2%(10g)
3	86%(430g)	2%(20g)	10%(50g)	2%(10g)
4	85%(425g)	3%(20g)	10%(50g)	2%(10g)
5	84%(420g)	4%(20g)	10%(50g)	2%(10g)

To improve the mechanical properties of modified AC2A alloy heat treatment process was done by Niyas Salim & Kumar [3] on mechanical test samples. Heat treatment process comprises mainly of Solution Treatment & Quenching followed by Artificial Ageing / Precipitation Heat Treatment.

Figure 3: Casting of Aluminium and Magnesium Mixture

2.4. Testing

In the first phase of testing the material has to be tested for OES. Inductively coupled plasma optical emission spectrometry (ICP-OES), is an analytical technique used for the detection of trace metals (ppb). It is a type of emission spectroscopy that uses the inductively coupled plasma to produce excited atoms and ions that emit electromagnetic radiation at wavelengths characteristic of a particular element. The intensity of this emission is indicative of the concentration of the element within the sample. Unlike atomic absorption spectroscopy, which can only measure a single element at a time ICP-OES has the capability to scan for all elements simultaneously. This allows rapid sample processing.

Optical microscope was used for microstructural studies of the as-cast and heat treated alloys of Al-Cu-Mg alloys [Nafsin & Rashed, 5].

Figure 4: ICP-OES Apparatus

The next test in the first phase is the **XRD** which stands for X-Ray Diffraction, it is performed for the identification and characterization of compounds based on their diffraction pattern. A chemical solution composed of 10cm3 of ferric chloride (FeCl3), 25cm3 of hydrogen chloride (HCl) and 75 cm3 of ethanol (CH3-CH2-OH) was used as etching agent before mounting on the microscope for microstructural examination of the specimen. A dispositioned sample can lead to unacceptable specimen displacement errors. Sample flatness, roughness, and positioning constraints preclude in-line sample measurement. After obtaining the OES and XRD the specimens or samples are sent for the tests of mechanical properties like tensile test, hardness test. The mechanical properties of the different form of samples with various compositions were studied. The tensile properties of the Al alloys under investigation were determined using universal tensile testing machine. The constituents formed in the alloys containing only one or more of copper, magnesium etc., are soluble ones [Kenneth & Michael, 11].

2.5. Identified Gaps in Paper

The method of addition of magnesium was not clearly mentioned by Salihu & AliyuIsah [10] and moreover if the magnesium had been added earlier there would be loss in the magnesium content.

Adeyemi et al., [6] mentioned in their conclusion that there was a reduction in the material's ductility and the impact strength as there was an increase in the amount of magnesium which was mentioned by Salihu & AliyuIsah [10].

The method of preparation of the binary and ternary aluminium alloy by Garcia-Garcia et al., [9] is not clearly explained but they have achieved higher corrosion resistance by the addition of magnesium and titanium.

III. Results

The OES test shows the variation in the chemical content of the aluminium alloy as the Magnesium is added in steps.

Table 2: Chemical Composition

Mg%	Alloy	Cu%	Mg%	Fe%	Si%	Mn%	Ti%	Zn%	Al%
0.0	**$AlCu_4Mg$**	4.25	0.0	0.26	0.24	0.3	0.02	0.04	Bal
0.5	**$AlCu_4Mg$**	4.30	0.79	0.26	0.24	0.3	0.04	0.04	Bal
1.0	**$AlCu_4Mg$**	4.38	0.98	0.28	0.24	0.4	0.05	0.06	Bal
1.5	**$AlCu_4Mg$**	4.30	1.5	0.28	0.24	0.4	0.05	0.06	Bal
2.0	**$AlCu_4Mg$**	4.75	1.97	0.28	0.24	0.4	0.05	0.06	Bal
2.5	**$AlCu_4Mg$**	4.89	2.28	0.3	0.24	0.4	0.06	0.07	Bal

It was clear that the tensile strength increases with increase of % Mg.

Table 3: Comparison of AS- Cast Alloy and HT Alloy

Mg%	Alloy	Tensile Srength (MPa) As Cast Alloy	Tensile Srength (MPa) Heat Treated Alloy	Yield Strength (MPa)	Hardness (BHN) As Cast Alloy	Hardness (BHN) Heat Treated Alloy
0.0	**$AlCu_4Mg$**	101.89	110.80	86.69	72.20	90.20
0.5	**$AlCu_4Mg$**	105.80	134.02	92.40	73.50	91.00
1.0	**$AlCu_4Mg$**	120.04	139.5	100.60	90.20	92.00
1.5	**$AlCu_4Mg$**	122.5	219.4	103.20	90.80	96.80
2.0	**$AlCu_4Mg$**	159.98	140.10	125.60	90.90	90.00
2.5	**$AlCu_4Mg$**	172.06	110.05	136.00	94.20	92.00

The graph below shows the tensile strength and yield strength of As-cast and Heat treated alloys and their variations.

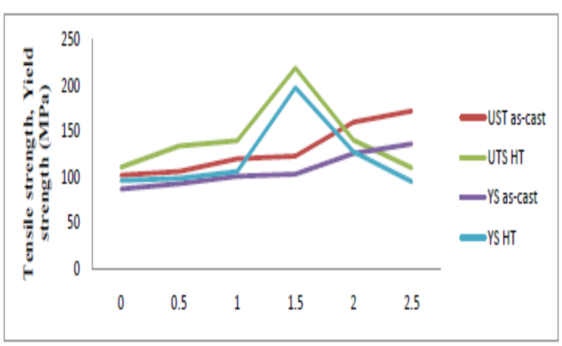

Figure 5: Graph- Tensile Strength vs Mg Content %

By increasing the content of magnesium, hardness and the tensile strength also increases with reference to as-cast condition, whereas the Heat treated alloy shows a very little variation in properties.

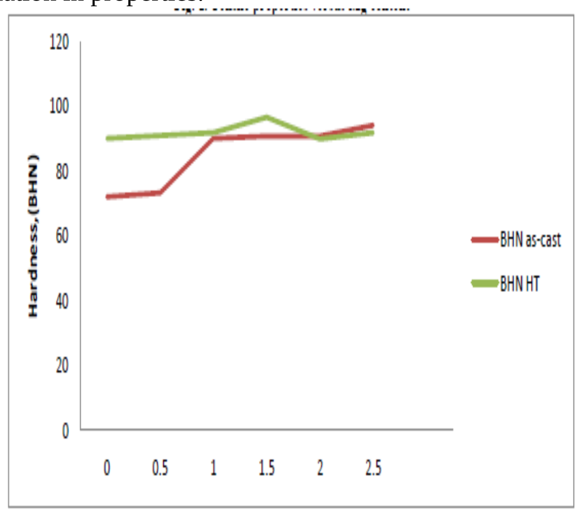

Figure 6: Hardness vs Mg Content%

The results shown above were obtained by Salihu & AliyuIsah [10] based on their research on the influence of magnesium addition on mechanical properties

Table 4: Aging Temperature and Strength

Wt% Mg	Aging temperature (^{0}c)	Holding time (Hrs)	Hradness (BHN)	UTS (MPa)
1	**180^0C**	2	116.2	401.3
1		4	116.5	403.4
1		6	116.9	408.6
1	**190^0C**	2	118.1	415.0
1		4	117.2	411.8
1		6	121.1	435.8
1	**200^0C**	2	117.0	410.9
1		4	117.9	414.8
1		6	118.8	422.1

The above table was the result obtained by Bansal et al., [2] and the hardness and tensile properties varied from the result obtained by Salihu & AliyuIsah [10].

Table 5: Hardness vs Mg% [Adeyemi et al., 7]

Serial Number	Wt% Mg inclusion	Dia of Indentation (mm)	Hardness (BHN)
1	0	2.5	9.98
2	1	3.0	14.47
3	2	3.8	23.56
4	3	4.0	26.23
5	4	4.2	34.40

IV. Conclusions

Niyas Salim & Kumar [3] concluded that the modified alloy showed a slight decrease in the impact value due to high Cu content and leads to the precipitation of CuAl2 phases. Microporosity usually resulting from the dissolved H2 and N2 gas was a reason for reduced impact strength of the alloy.

From their paper it can be said that the variation in properties are not uniform for all alloys and it may change accordingly.

Bansal et al., [2] obtained different results of tensile and hardness values when the similar aluminium alloy with the same amount of magnesium addition was treated by strain aging after the casting process.

It can be understood that the values vary largely when a different type of secondary treatment is provided.

The similar technique could be applied for the recycling of aluminium, because when aluminium is recycled a lot of magnesium is lost due to its low melting point compared to aluminium [Jirang & Roven, 7].

According to Girisha, and Sharma [8] the main benefit of adding magnesium to aluminum-copper alloys is the increased strength and hardness possible following solution heat treatment and quenching.

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