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EXPERIMENTAL INVESTIGATION OF DIFFERENT MAGNESIUM ADDITION ON THE COMPRESSION STRESS OF ALUMINUM 19% SILICON ALLOYS

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ABSTRACT

This research focuses on the effect of the magnesium concentration in aluminum alloy 19% Silicon by weight. All alloys with the various percentages of the magnesium (0.5, 1, 2.5, 3.5, 4and 5.5% by weight) were prepared by using gravity die casting. This process was used to investigate the influence of the magnesium concentration on the microstructure and mechanical characteristics for the tested aluminum alloy such as hardness and compression strength. The microstructural test results showed that the existence of the primary silicon (Si) and the eutectic (silicon+ aluminum) phases were distributed uniformly in the structure. Also, the results found that both the compression strength and the hardness were increased with the rise of the magnesium content added to the Al-19% Si alloy. The best result was observed at percentage of 4% magnesium compared to the previously mentioned percentages.

Key words: Aluminum -19%Si Alloy, magnesium effect, mechanical properties, microstructure

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1. INTRODUCTION

The characteristics of aluminum alloys depend on the type and portion of the alloying elements such as magnesium, zinc, silicon, copper, etc. These elements have a great impact on the mechanical properties of the resultant alloy when the composition was changed. The characteristics are also affected by the manufacturing techniques and the implemented heat treatment processes [1]. Metallic alloys were influenced by the existence of Silicon because of its high casting qualities in comparison to other alloys. Also, it is added to reform the liquidity of the smelt and it decrease the fusion temperature, and shrinkage through hardening, while it is inexpensive as raw material. The Binary aluminum-silicon alloys have many characteristics such as great corrosion resistance, good weld-ability, low specific gravity and great bunch of physical properties compared to the other aluminum alloys. In addition, Silicon has a very little dissolution in Aluminum and it precipitates as practically pure Si which is rigid and improves the scrape "resistance". Also, it decreases "thermal expansion coefficient" of the Al-Si alloys. Adding Silicon to Aluminum enhance the "Machinability". Generally, Hypereutectic (14-25 % Si by weight) are used as substitute for cast iron for many applications such as gas lining, pistons, connecting rods and sockets in fragrant compressors [2 ,3]. Magnesium (Mg) is the source of strength and perfection of the "work-hardening" quality of aluminum. It tends to have a "good corrosion resistance", weldability and a very great Strength. The combination of Mg and Si will give Mg_2Si which is the main resource of high strength [2,4]. The addition of the Si content to the aluminum lead to increase the "elastic modulus", "thermal dimensional stability" , "thermal conductivity" and "bending strength". The best Si concentration in the alloy is 12%. Adding more Si will decrease "the coefficient of thermal expansion (CTE) "of the composites. The best concentration of the Mg in the aluminum was 4–8 % by weight. Further, this composites show a good thermo-mechanical qualities. Many studies were performed in this field such as M. Gupta, et al Sling [3]. In their study, three aluminum alloys that had silicon content of 7, 10 and 19 % by weight were investigated experimentally. The alloys were prepared using disintegrated melt deposition technique. Shrinkage cavity was deformed from the ingots through casting process which improve the yield up to 80%.The Microstructure test showed increasing in the volume fraction of porosity by increasing the silicon content. While mechanical examinations showed a rise in micro hardness and yield stress with a reduction in ductility with the increase in silicon content in aluminum. This decay was treated by extrusion process, which reduced the porosity and enhances the uniformity of microstructure, yield strength, ultimate tensile strength and ductility comparing with the un-extrusion Al–19%Si alloys. Muna K. Abbass [5], investigate the effect of applied casting pressure at constant pouring and die preheating temperatures on the microstructure and dry sliding wear behavior for the squeeze cast Al-12%Si alloy. The results showed that the microstructure refined due to the increase the squeeze pressure from 7.5 to 53 MPa. Also, high squeeze pressure increases the hardness and decrease the wear rate. Muna Abbass [6] and Sunil Kumar [7] studied the effect of the Cadmium (Cd) addition and microstructure on the dry sliding wear behavior of the Al-12%Si Alloy. They concluded that the wear resistance increases as the Cd addition increased and also refined the microstructure which includes the Si particles and the α-Al dendrites grains. Nikanorova and Volkova[8] studied the structure and mechanical qualities of the cast Al–Si alloys for hypo and hyper-eutectic which was prepared by using rapid cooling from melts solutions for the different range of the silicon (11.5wt% to 35 wt.% Si) .They found that the properties depend on several elements through alloys solidification. Further, the importance of the yield point was described by the Plasticity of components of the eutectic structure, primary crystals and grain boundaries. It was explained that the extreme of the concentration relies on the mechanical qualities for the fine-grained structure rose from coupled eutectic growth. Solidification, on the other hand, was highly influenced by the primary crystals of solid solution or the primary Si crystals. Geoffrey K. Sig worth [9], show that the chart which obtained from solidification process helped to conclude the phases of alloy elements. Growing and coarsening of dendrites is happened as a result of secondary dendrite arm spacing (SDAS) which related to spatial solidification time. The segregation is revised controls that made for solidification phases in the Al-Si casting alloys and plans are invested to improve the compositions of casting alloy. Rajneesh Kumar Verma[10] studied the changing in composition by change the Copper content and its influence on the mechanical characteristics such as the tensile Strength, the hardness and the corrosion resistance in the Aluminum-Silicon-Copper alloy. The alloy was prepared using the sand casting technique to achieve the purpose of the research, and testing was performed on the samples which were prepared from ingot alloys to determine the resultant mechanical properties which were improved by increasing the copper percentage. Muna K. Abbass et al. [11] studied the effect of the magnesium addition on the corrosion resistance of the aluminum 17% silicon alloy. Corrosion behavior was investigated by using potentiostat instrument under static potentials test and corrosion current was recorded to determine the corrosion resistance of all prepared samples. It was found that the addition of the Mg metal improves the corrosion resistance of the Al-17%Si alloy in 3.5%NaCl solution. The alloy containing 1%Mg showed less corrosion rate than the others while the alloys containing 4.5%Mg to 9%Mg content have the better pitting corrosion resistance than other alloys.

The objective of the present work is to improve the compressive strength and hardness of the hypereutectic Al-19% Si alloys by magnesium addition at different percentages. Additionally, a detailed investigation of the microstructure observations was introduced to verify the enhancement that could happen in the mechanical properties.

2. EXPERIMENTAL WORK

2.1. Materials

The basic alloy (Al-19% Si) has a several applications such as pistons liner-less engine blocks and compressor parts. In this investigation, the chemical analysis was performed for the tested alloy using the ARL spectrometer device and the obtained results are listed in the Table (1).

Table 1 The analysis results of Al-19%Si alloy.

Element wt%	Si%	Fe%	Cu%	Mn%	Mg%	Cr%	Ni%	Zn%	Sn%	Pb%	Al%
Actual value	17.1	0.6	0.81	0.252	0.184	0.026	0.36	0.22	0.059	0.214	Rem.
Standard value	19	1.0	1.3	-	1.0	0.1	1.3	0.25	-	-	Rem

2.2. Preparation of Composite Materials

Graphite crucible was used to melt the basic Alloy of the Al 19%Si by putting it in an electric furnace at temperature of 780º C then the molten metal was poured in the cylindrical steel pre heated die with diameter of 14mm and a height of 120mm. After that, the pre-determined percentage of Mg particles was added to the matrix of the Al -19% Si using a stir-casting method for materials preparation. Many steps were used to prepare the composite material, starting by smelting the basic alloy then moving the smelt using mechanical stir, dissolving 5% from Mg in the smelt by stirring speed of 600 rpm for 5 minutes. Finally, effuse the smelt in the steel template. Similar process was implemented to prepare other composite materials having series percentage of magnesium particles in the matrix alloy of 10%, 25%, 30%, 35%, and 40%.

2.3. Categorization of Cast Ingot

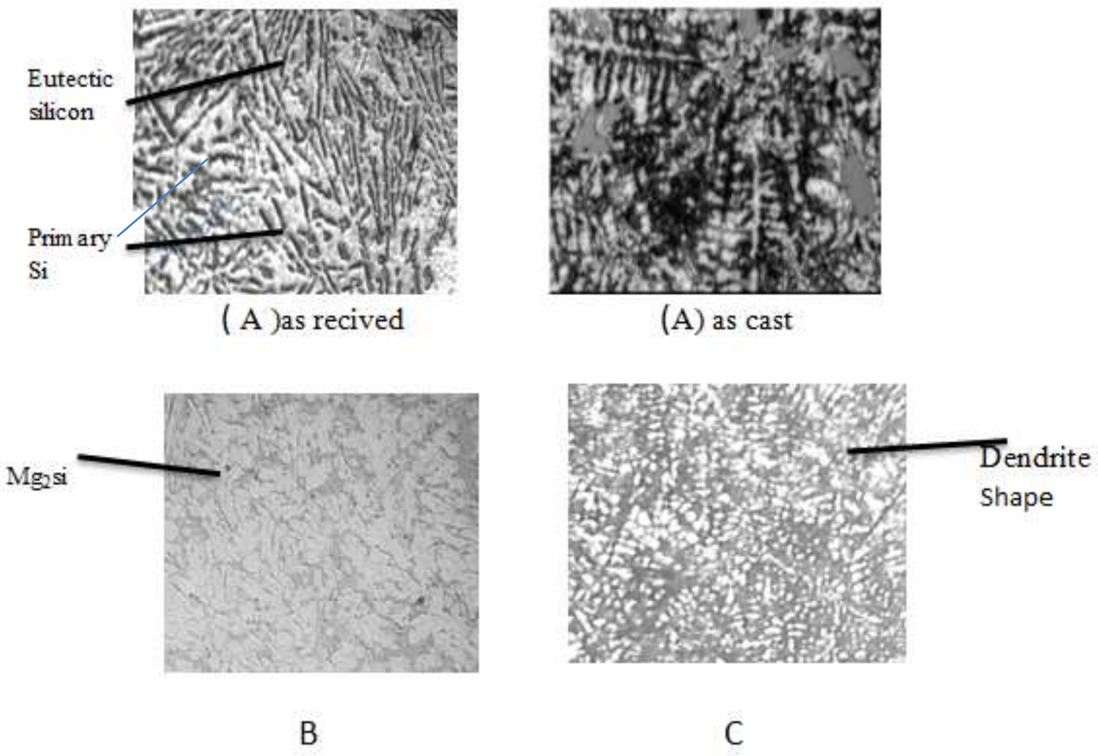
The cast ingot which used in this investigation was classified into seven groups as listed in Table (2).

Table 2 Grouping of Specimens for Al-Si alloy

Specimen's symbol	State of Specimens
A	Alloy without addition
B	Alloy with addition (0.5% by weight)
C	Alloy with addition Mg (1.0% by weight)
D	Alloy with addition Mg(2.5% by weight)
E	Alloy with addition Mg(3.5% by weight)
F	Alloy with addition (4% by weight)
G	Alloy with addition (5.5% by weight)

2.4. Microstructure Test

Many steps were carried out to prepare the specimens for microstructure examination, including grinding process for one surface by emery paper of SiC for diverse grits of (220,320,500, and 1000). Polishing process was also carried out in this investigation using the diamond paste of size (0.5µm) with special polishing cloth and lubricant. Etching process was done by using etching solution composed of 99% H2O+1%HF. Then, the samples were washed and dried using water and alcohol. Optical examination of samples was performed using optical microscope equipped with camera and connected to a computer as shown in Fig (1).



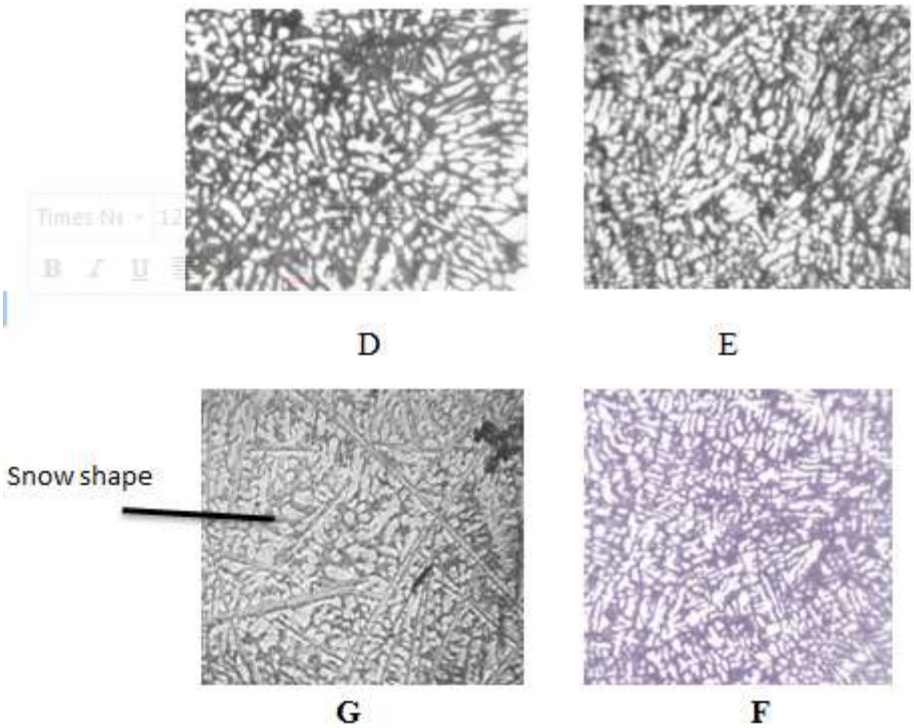


Figure 1 Microstructure of all specimens

2.5. Hardness test

The results of macro hardness test of all specimens are listed in Table (2) which were carried out by using a Rockwell B-Scale Hardness Testing Machine. Three indentations were made on the surface of each sample and the hardness values were listed in Table (3)

2.6. Compression tests

The dimension of the compression specimens was (15mm in length × 10 mm in diameter) which manufactured according to the ASTM B557M84. Compression characteristics were computed at room temperature using the computerized Olsen universal compression testing machine at a fixed crosshead speed of 3 mm/min. The results are listed in Table (3) and the relation between load and extension is presented in Fig. (2A,B). Optical microscopic was used to display the specimens after compression test as shown in Fig. (3). Also, the SEM was used to record the fracture behavior after the test for specimens B, C and D with the clear phased specimens E and G as shown in Fig. (4).

Table 3 Mechanical results of all specimens.

Specimens symbol	**Yield Compression stress Mpa**	**Ultimate Compression stress Mpa**	**Fracture stress Mpa**	**Strain(ε)**	**Modules of Elasticity Mpa**	**Hardness by Rockwell B kg/mm^2**
A	80.8	129.6	80.2	1.8	4001.04	85
B	145.2	209.1	95.87	2.4	7838.05	82
C	271.28	273.59	52.08	3	7401.83	70
D	214.4	281.74	90.78	4.5	7428.07	66
E	299.92	427.76	96.32	3.7	8001.27	63
F	339.85	677.49	103.26	7.1	8405.9	56.5
G	316	358.6	90.78	4.3	7428.07	56

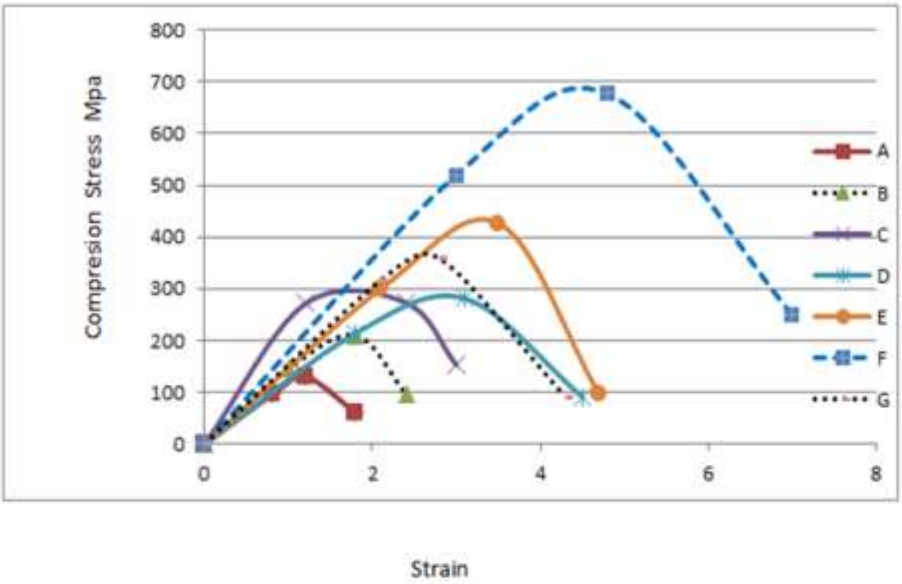


Figure 2 Relationship between Compresion Stress and Strain after compresion test

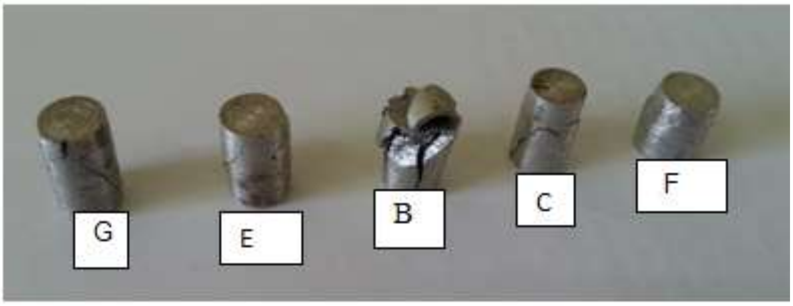
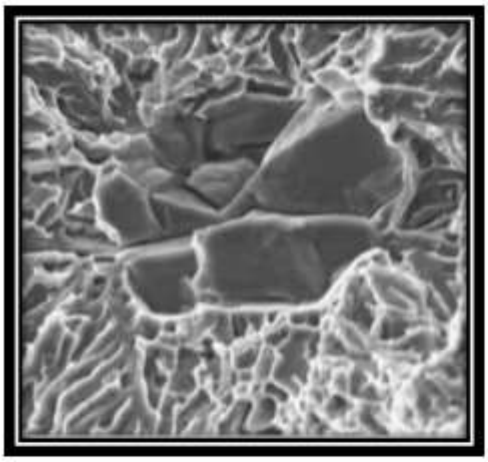
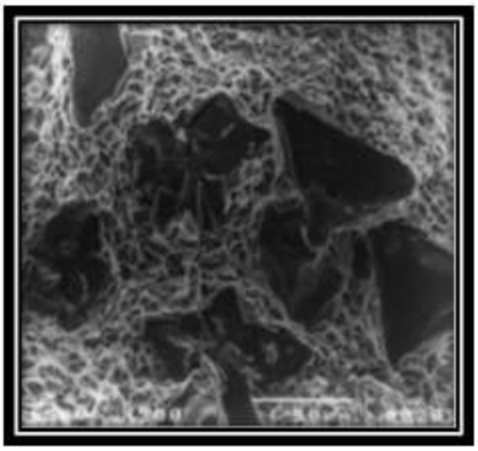


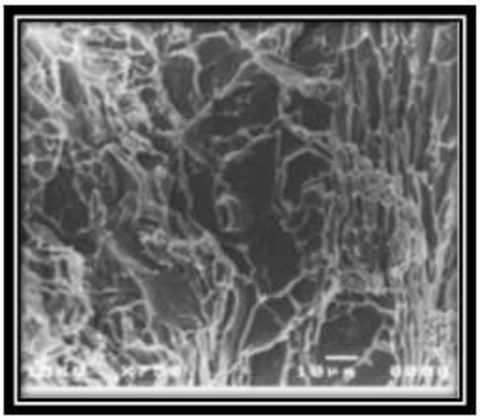
Figure 3 Photo for specimens after compression test

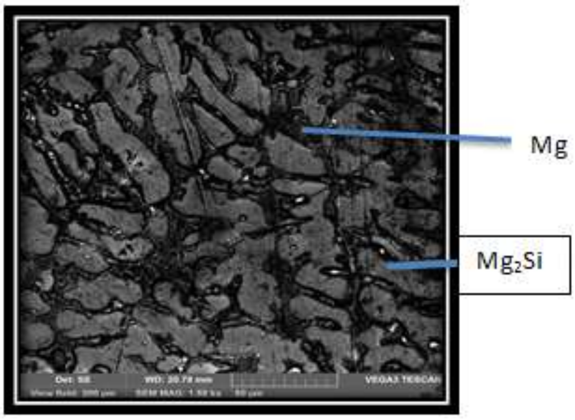


B



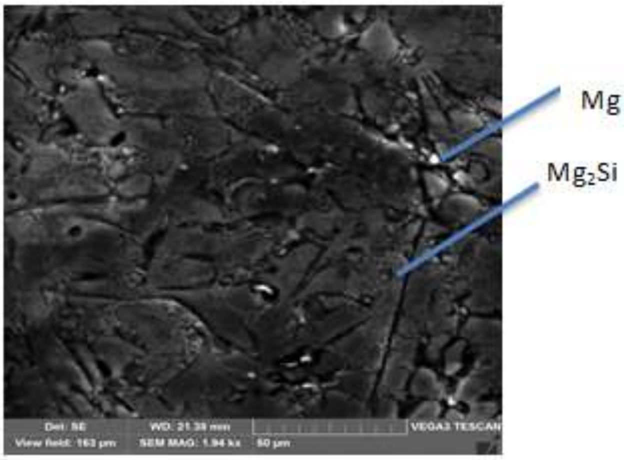
C





E

D



F

Figure 4 SEM fracture surface image and phases for specimen (B,C,D,E, F)

3. DISCUSSIONS

From Fig. (1A) it was observed that the microstructure contains the primary silicon (Si) in blocky shape and eutectic silicon with large needle shape phases for the matrix of Al-19%Si alloy. The main sign is that the alloys conformation dendrites shaped due to the addition of the silicon or other elements to the aluminum which is never seen in pure metals. In Fig.(1B), it was observed that the (alloy Mg_2Si) hardening phase shaped due to combination of the Silicon with magnesium when it is added to alloys at 5% which delivers certain amount of the strengthening. The hardness and strength values arise as an outcome of sedimentation of novel sediment due to heat cycle from supersaturated solid solution. Fig. (1C, D, E, F and G) show the microstructures of specimens having dendrites shape. The arms on the outlets of the dendrite are thin in specimens (C, D and E) and the dendrites are increasing easily into liquid metal. Essentially, they are motionless and with no contact with neighboring grains. For some points, the trunks of the dendrites come in contact with neighboring grains (in this period of contact is called dendrite coherency). After that, any further solidification (growth of dendrites) can occur only by thickening with the snow flake analogy. The aluminum grain is growing and it takes the shape of snow which represented in Fig. (1F, G). It was found that the compression stress increases with increasing in the magnesium percentage. Alloys relied not only on their chemical composition but are also significantly relied on Microstructure configuration. Fig. (3) confirmed this result for all specimens and Fig. (4) shows the SEM photograph and the result of Si was clear on section fracture of specimens (B, C, D). Also, phases are clear in Fig (4 E, F) as result of saturated of magnesium element.

4. CONCLUSIONS

It was found that the compressive strength and hardness increase as magnesium addition increases. The precipitation processes of the Mg_2Si in the Al matrix of all the precipitated phases can be controlled by the diffusion process of elements. The SEM and optical micrographs for specimens with free magnesium have coarse dendrites shape of the α-Al phase and needle shape of the Si particles**.**

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