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The Effect of Plastic Deformation and Magnesium Content on the Mechanical Properties of 6063 Aluminium Alloys

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ABSTRACT

In order to determine the effect of increased magnesium addition on the strengthening behaviour during deformation, four types of aluminium alloys were cast and rolled. The cast aluminium alloys contain; 0.451%Mg, 0.551%Mg, 0.651%Mg, and 0.751%Mg in addition to the other elements which are constant. Deformation was carried out at 20% and 40%. The hot worked profiles were machined into tensile test specimen and were subjected to tensile test. The result was used to determine the ultimate tensile strength and the percentage elongation. From the results, it was observed that the tensile properties of the aluminium alloys improved with increase in percentage deformation and magnesium content up to 0.651%Mg. This shows the effect of deformation on grain refinement. At high percentage of deformation and increased magnesium content, the grains are more refined and this improves the strength and the mechanical properties. However, at 0.751%Mg, a decrease in the tensile properties was observed as deformation is no more effective. The result shows that there is a limit to the amount of magnesium content that will give the optimum mechanical properties.

Keywords: *aluminium, magnesium,cast,plastic deformation, mechanical properties, strengthening.*

1. INTRODUCTION

Pure aluminium is a weak and ductile material. However, the presence of a relatively small percentage of impurities in aluminium considerably increases the tensile strength and hardness of the material (Bolton, 1999).

The mechanical properties of aluminium and its alloys depend not on the purity of aluminium but on the amount of work to which it has been subjected. The effect of working is to fragment the grains. This results in an increase in tensile strength and hardness and a decrease in ductility (Bolton, 1999).

The 6000 series alloys have recently found increased application in automotive and construction industry. Therefore, several research works have been undertaken to strengthen the alloys either by small addition of copper, magnesium, zinc and/or silicon (Moons, et al, 1996) or by a predeformation treatment (Matsuda, et al, 1999).

The development of Al-Mg-Si alloys for light structures has led to an increasing market for extrusions of intricate shape, medium strength and good toughness. These alloys are required to meet specific tensile properties and fatigue strength, welding characteristics and formability (Kemal et al, 2005).

In this paper is the result of the findings on the effect of deformation and magnesium content on the tensile properties of 6063alloys.

2. EXPERIMENTAL PROCEDURE

Four alloys of the compositions given in Table 1 were cast in form of rods of dimension 5000mmx12mm.

Table 1. Chemical Composition of the Aluminium Alloys. (Wt %)

Alloys/Comp.	Fe	Si	Mn	Cu	Zn	Ti	Mg	Sn	Pb	Al
I	0.336	0.456	0.037	0.050	0.127	0.014	0.451	0.01	0.08	98.44
II	0.336	0.456	0.037	0.050	0.127	0.014	0.551	0.01	0.08	97.89
III	0.336	0.456	0.037	0.050	0.127	0.014	0.651	0.01	0.08	97.79
IV	0.336	0.456	0.037	0.050	0.127	0.014	0.751	0.01	0.08	97.69

The aluminium alloys were hot worked by rolling them at 20% and 40% deformation after holding in the furnace at 450^0C and soaked for 30 minutes. The deformed rods were machined on the lathe to tensile specimens and tensiometer was used to carry out the test.

2.1 Tensile Test

The specimen was clamped to the teeth of the tensiometer and load was gradually applied manually. The value of the applied load was indicated by the pointer in the mercury bulb. The effect of this load was also displayed on the graph sheet that was fixed at one end of the machine. The applied load stopped immediately the specimen breaks and the graph show the relation between the load and the extension produced. The percentage elongation was determined from the specimen with the aid of vernier caliper. The percentage elongation of a test piece after breaking is used as a measure of ductility;

$$\text{Percentage elongation} = \frac{\text{final length} - \text{initial length}}{\text{Initial length}} \times 100\% \quad \text{(Bolton, 1999)}$$

3. RESULTS AND DISCUSSION

Deformation is one of the most important parameters in increasing the mechanical properties of aluminium and its alloys. Figures1a, 2a and 3a show the dependence of the ultimate tensile strength of 6063 alloys on the degree of deformation.

3.1 Aluminium Alloy Sample with 0.451%Mg

Figure 1a shows the average stress-strain curve of the samples. Samples deformed at 40% have increased tensile properties of 241.34N/mm^2 UTS than those deformed at 20% with 202.24N/mm^2 UTS.

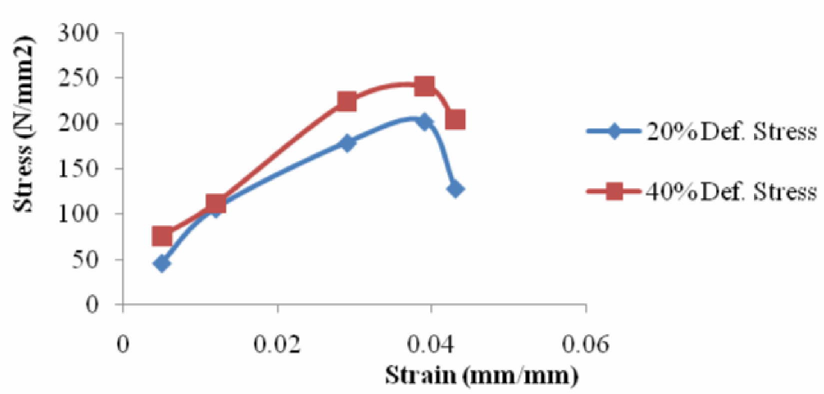

Figure 1a: Average Stress-Strain Curve for Samples with 0.451%Mg Deformed at 20% and 40%.

Figure 1b shows the graph of percentage elongation of the deformed samples. Samples deformed at 20% have high percentage elongation of 4.40% than those samples deformed at 40% with 3.95% elongation.

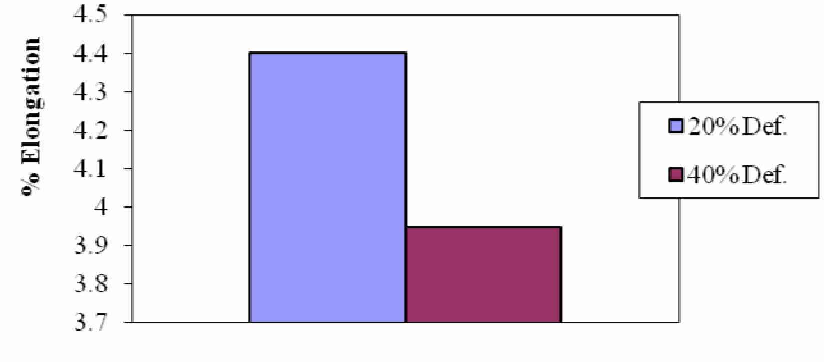

Figure 1b: Graph of Percentage Elongation for Sample with 0.451%Mg Deformed at 20% and 40%.

3.2 Aluminium Alloy Sample with 0.551%Mg

Figure 2a shows the average stress-strain curve of the samples. Samples deformed at 40% have increased tensile properties 251.67N/mm^2 UTS than those deformed at 20%that has 196.73N/mm^2 UTS.

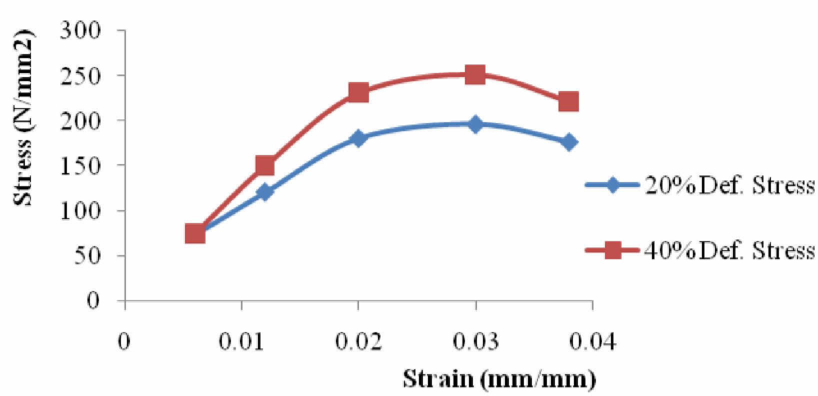

Figure 2a: Average Stress-Strain Curve for Sample with 0.551%Mg Deformed at 20% and 40%.

Figure 2b shows the graph of percentage elongation of the deformed samples. Samples deformed at 20% have high percentage elongation of 4.40% than those samples deformed at 40% with 3.90% elongation.

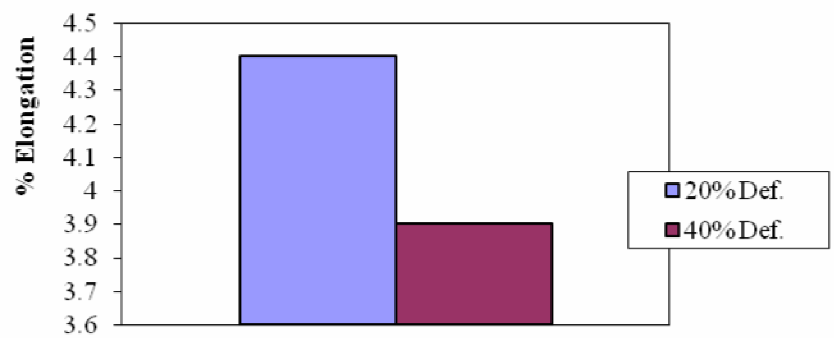

Figure 2b: Graph of Percentage Elongation for Sample with 0.551%Mg Deformed at 20% and 40%.

3.3 Aluminium Alloy Sample with 0.651%Mg

Figure 3a shows the average stress-strain curve of the samples. Samples deformed at 40% have increased tensile properties of 258.03N/mm^2 UTS than those deformed at 20% which has 215.10N/mm^2 UTS.

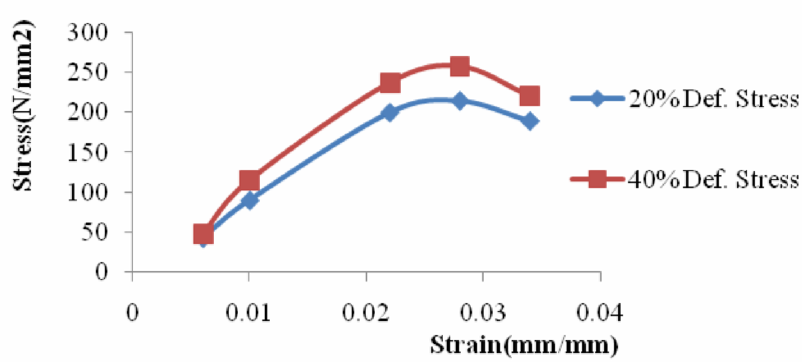

Figure 3a: Average Stress-Strain Curve for Samples with 0.651%Mg Deformed at 20% and 40%.

Figure 3b shows the graph of percentage elongation of the deformed samples. Samples deformed at 20% have high percentage elongation of 3.48% than those samples deformed at 40% with 3.13% elongation.

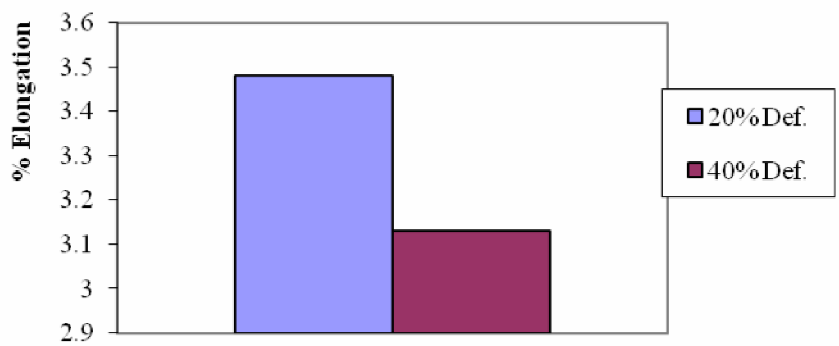

Figure 3b: Graph of Percentage Elongation for Sample with 0.651%Mg Deformed at 20% and 40%.

3.4 Aluminium Alloy Sample with 0.751%Mg

Figure 4a shows the average stress-strain curve of the samples. Both samples that were deformed at 40% and 20% have 179.14N/mm^2 and 180.64N/mm^2 UTS respectively.They experienced almost the same increase in tensile properties.

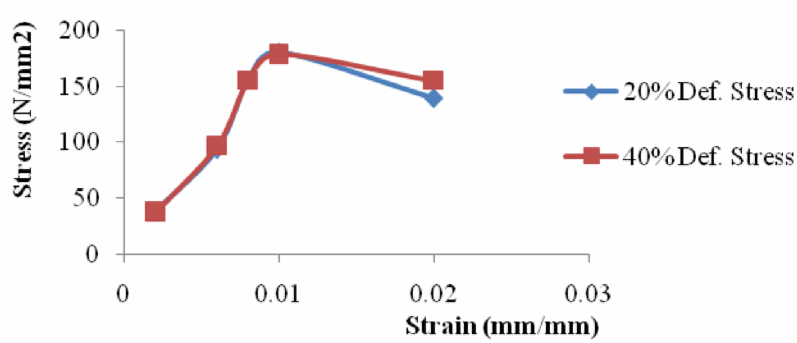

Figure 4a: Average Stress-Strain Curve for Samples with 0.751%Mg Deformed at 20% and 40%.

Figure 4b shows the graph of percentage elongation of the deformed samples. Samples deformed at 40% have high percentage elongation of 2.50% than those samples deformed at 20% which has 1.70% elongation. This shows that the samples deformed at 40% is more ductile than the first three samples that were deformed at 40%.

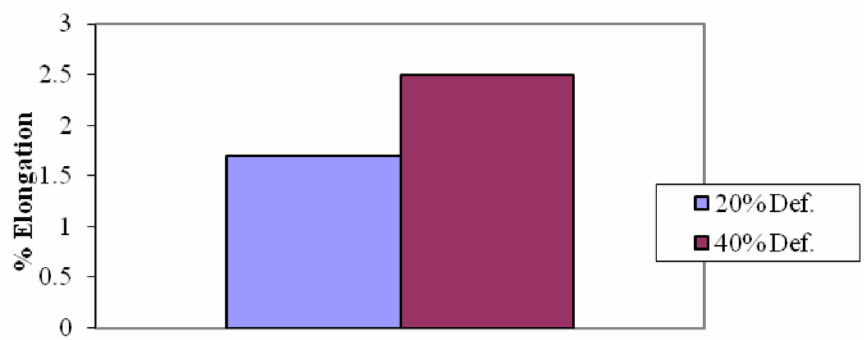

Figure 4b: Graph of Percentage Elongation for Sample with 0.751%Mg Deformed at 20% and 40%.

The progressive increase in the tensile strength as the magnesium content increase from 0.451% to 0.651%Mg content as shown in Figures1a, 2a, 3a that, both the percentage deformation and magnesium content affect the mechanical properties of 6063 aluminium alloys.

When the alloying element was increase to 0.751%Mg, deterioration in the tensile properties was observed. At this composition, 40% deformation causes a small decrease in the tensile properties than what obtained at 20% deformation. (Figure 4a).

The ductility of the materials as shown by the graphs of percentage elongation of the samples Figures 1b, 2b, 3b, 4b revealed that as the tensile strength increases, the hardness also increases. This was shown by the decrease obtained in the ductility of the samples with increase tensile strength (Figures 1b, 2b, 3b) and increase in the ductility of the sample with low tensile strength (Figure 4b).

Magnesium additions on wrought aluminium alloys allow the formation of complex precipitates that not only retard grain growth during ingot reheating but also assist in grain refinement during rolling (Davids, 1996). The improvement on the mechanical properties was as a result of the fine grain structure produced from the increased magnesium content and percentage deformation. This was in accordance with the Hall-Petch equation (Donald, 1990). The equation ascertains that, the finer the grain size, the greater the strength of such material. It is however noted that the mechanical properties of alloy sample with magnesium content of 0.751% dropped as a result of the coarseness of its grains.

4. CONCLUSION

The effect of plastic deformation and magnesium content on the mechanical properties of 6063 aluminium alloys was observed. Deformation at 40% gave good tensile properties than deformation at 20% up to 0.651%Mg content. Hence, the mechanical properties of the samples increase with an increase in percentage deformation and magnesium content up to 0.651%Mg. Therefore, for improved mechanical properties of 6063 aluminium alloys deformed at 40%, the magnesium content should be kept between 0.451% and 0.651%.

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