Effect of Silicon content on the Mechanical Properties of Aluminum Alloy

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Abstract - Aluminium alloys are widely used in automotive industries. This is particularly due to the real need to weight saving for more reduction of fuel consumption. The typical alloying elements are copper, magnesium, manganese, silicon, and zinc. Surfaces of aluminium alloys have a brilliant lustre in dry environment due to the formation of a shielding layer of aluminium oxide. Aluminium alloys of the 4xxx, 5xxx and 6xxx series, containing major elemental additives of Mg and Si, are now being used to replace steel panels in various automobile industries. In this work we are interested to investigate the mechanical properties of aluminium alloy by varying the percentage of silicon. The results showed that with the increasing of silicon content the solidification time increased, as also a decreasing the liquids temperature. The tensile strength of aluminium alloy is increased with increased silicon content up to 6 %.

Key Words: Silicon, Aluminium, Aluminium Alloy, Ultimate Strength

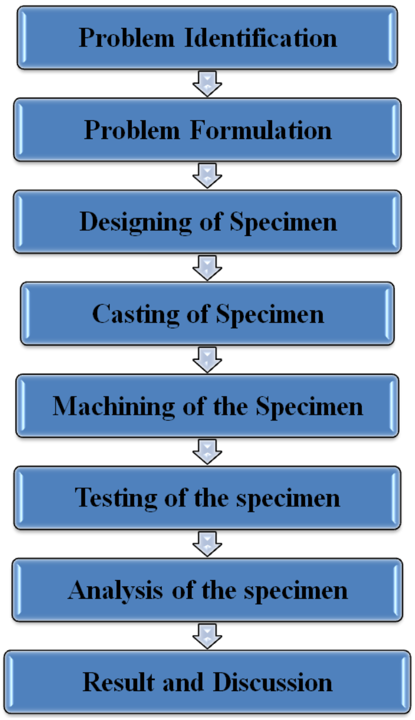
1. Introduction

An alloy is a material that has metallic properties and is formed by combination of two or more chemical elements of which at least one is a metal. The metallic atoms must dominate in its chemical composition and the metallic bond in its crystal structure. Commonly, alloys have different properties from those of the component elements. An alloy of a metal is made by combining it with one or more other metals or non-metals that often enhances its properties. For example, steel is stronger than iron which its primary element. The physical properties, such as density and conductivity, of an alloy may not differ greatly from those of its component elements, but engineering properties such as tensile strength and shear strength may be considerably different from those of the constituent materials[1]

The tribological properties of Al-Si alloys are affected by shape and distribution of silicon particles, and addition of alloying elements such as copper, magnesium, nickel, and zinc often combined with a suitable heat treatment [1-3]. The excellent tribological properties Al-Si alloys have led to their extensive uses in engineering application, particularly in plain bearings, internal combustion engine pistons, and cylinder liners [4, 5]. Silicon is present as a uniformly distributed fine particle in the structure. However, when the primary silicon appears as coarse polyhedral particles, the strength properties decrease with increasing silicon content, but the hardness goes on increasing because of the increase in the number of silicon particles [6]. The high-temperature creep resistance of magnesium alloys was discussed, with special reference to Mg-Al and Mg-Y alloys. Mg-Al solid-solution alloys are superior to Al-Mg solid-solution alloys in terms of creep resistance. This is attributed to the high internal stress typical of an HCP structure having only two independent basal slip systems [7]. Manganese is also able to change the morphology of the iron-rich phases from platelets to a more cubic form or to globules. These morphologies improve tensile strength, elongation, and ductility [8,9]. If the iron content exceeds 0.45 wt.%, it is reported that the manganese content should not be less than half of the iron [10].Aluminium alloys with silicon as a major alloying element are a class of alloys, which are the basis of many manufactured castings. This is mainly due to the outstanding effect of silicon in the improvement of casting characteristics, combined with other physical properties, such as mechanical properties and corrosion resistance [11]. Silicon is not only the most frequent impurity in commercial pure aluminium, but also the most common alloying element [12]. The influence of the Si content of the aluminium alloys on their wear resistance has been well documented and eutectic alloys are reported to have better wear resistance than those of hypoeutectic and hypereutectic composition [13]. Forged wheels have been used where the loading conditions are more extreme and where higher mechanical properties are required. Aluminium alloys have also found extensive application in heat exchangers. Modern, high performance automobiles have many individual heat exchangers, e.g. engine and transmission cooling, charge air coolers (CACs), climate control, made up of aluminium alloys [14].

The several methods for estimating fatigue properties of wrought aluminium alloys from simple tensile data or hardness was discussed. Among them, Park-Song modified Mitchell's method provided the best estimation results in low fatigue life regime [15].
The retrogression heat treatment is performed on Alloy AA 7075-T6 at various temperatures and hold times, and subsequent aging is performed at 130� for 12 h. The microstructure and mechanical properties of the alloy are studied depending on the temperature and the hold time of the retrogression heat treatment. Electron microscopic studies are preformed and mechanical characteristics are determined in tensile and impact tests [16]
In this work we investigate the mechanical properties of aluminium alloy to vary the percentage of silicon, using specimens prepared with reference to ASTM D638-02 a [17].

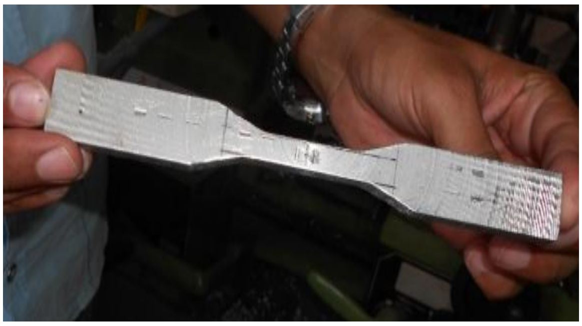
2. Experimental Procedure:



In this process, the metal which has highest melting temperature is firstly poured in the crucible and allowed to melt on the furnace. The metal which posses low melting temperature is allowed to melt in the last because if it will allowed to melt with metal which posses highest temperature then lowest melting temperature metal will get burn

(a)

(b)



(c)

Figure 1: (a) Pouring of molten metal into mould cavity, (b) Unfinished Product, (c) Finished Product

After pouring molten metal in the mould cavity allows solidifying into the mould cavity. The solidification time of the molten metal is given by Kornichov's Criterion.
According the Kornichov's criterion, the solidification time of the molten metal in the mould cavity is directly proportional to the square of the ratio of volume to the surface area of the cavity.

$$T_s \propto [v/S.A]^2 \quad (1)$$

$$T_s = k\,[v/S.A]^2 \quad (2)$$

T_s = Solidification Time
k = Constant of proportionality
V = Volume of the cavity
S.A. = Surface area of the mould cavity

Table 1:- Dimensions of Test Specimen

Dimension (mm)	Thickness 7mm or less		over 7 to 14 mm
	Type-I	Type-II	Type-III
W- Width	13	6	19
L-Length	57	57	57
WO-Width over all	19	19	29
LO Length over all	165	183	246
G-Gage length	50	50	50
D- grips Distance	115	135	115

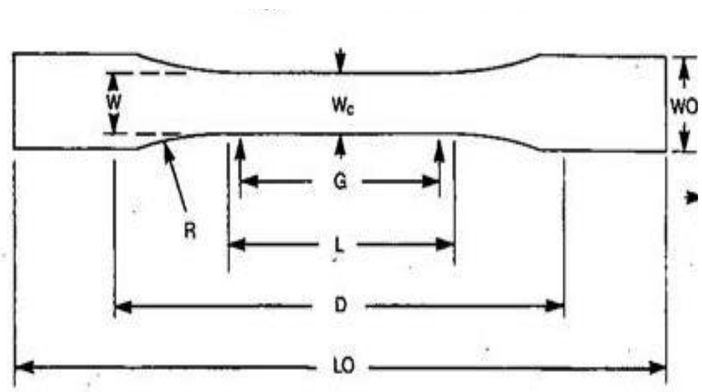


Figure 2:- Drawing of Test Specimen

The specimens 1 and, 2 are made with the help of ASTM code D638-02 a [21] and have the characteristics.
Specimen 1 made of Type-I
Specimen 2 made of Type-II

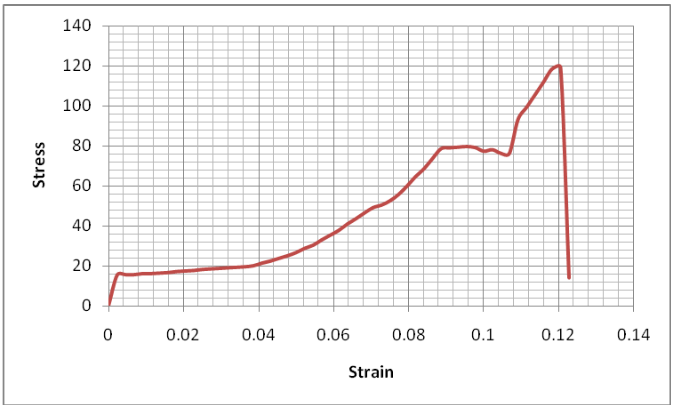
Table 2:- Composition of Aluminium Alloy

Alloying components	Al-Alloy Si-1.5%	Al-Alloy Si-3%	Al-Alloy Si-4.5%	Al-Alloy Si-6%
Silicon	1.5	3	4.5	6
Aluminium	92.9	91.4	89.9	88.4
Copper	3	3	3	3
Iron	0.8	0.8	0.8	0.8
Manganese	0.4	0.4	0.4	0.4
Nickel	0.3	0.3	0.3	0.3
Zinc	0.5	0.5	0.5	0.5
Lead	0.1	0.1	0.1	0.1
Tin	0.1	0.1	0.1	0.1
Titanium	0.2	0.2	0.2	0.2
Magnesium	0.2	0.2	0.2	0.2

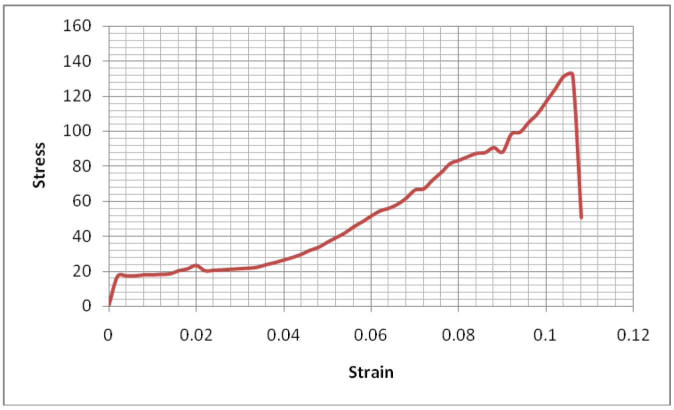
3. Result and Discussions:

Silicon is the most important single alloying element used in majority of aluminum casting alloys. It is primarily responsible for high fluidity, low shrinkage, low density which may be advantage in reducing total weight of cast component and has very low solubility in Aluminum therefore precipitates as virtually pure Si which is hard and improve the abrasion resistance. Si reduces thermal expansion coefficient of Al-Si alloys

Material	Specimen	Ultimate Tensile Strength (N/mm^2)	Mean Ultimate Tensile Strength (N/mm^2)
Al-Alloy (1.5 % Si)	1	119.21	120.87
	2	122.54	
Al-Alloy (3.0 % Si)	1	129.12	130.88
	2	132.65	
Al-Alloy (4.5 % Si)	1	138.24	139.74
	2	141.25	
Al-Alloy (6.0 % Si)	1	148.74	148.99
	2	149.25	



(a)



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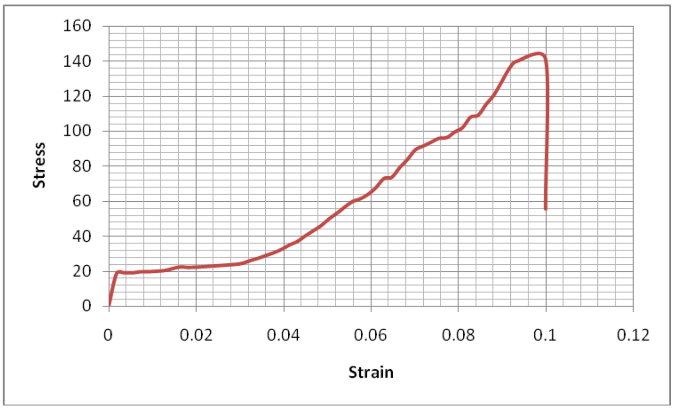

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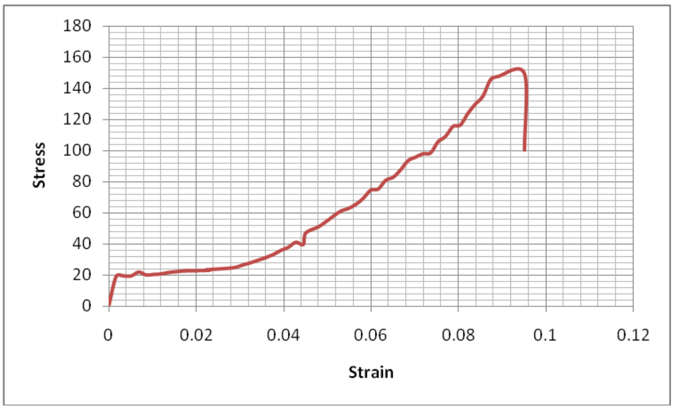

(d)

Figure 3:- Stress Strain Diagram for Aluminium Alloy (a) Si-1.5%, (b) Si-3%, (c) Si-4.5%, (d) Si-6%

The stress-strain curve for Aluminium specimens with an enlarged scale, now showing strains from zero up to specimen fracture. Here it appears that the rate of strain hardening diminishes up to UTS (Ultimate Tensile Strength).Beyond that point, the material appears to strain soften, so that each increment of additional strain requires a smaller stress.

A Study on Mechanical Properties of Aluminium Alloy with variation of Silicon element, tensile test is carried out at room temperature using universal testing machine.

The variation of the silicon particles in aluminium alloy as shown in table -2. It can be seen that the ultimate tensile strength of aluminium alloy is increased with increase in silicon content as shown in table 3. The density of the alloys decreased as the silicon content increased. The maximum tensile strength was found in Aluminium alloy (6% of silicon) 148.99 MPa, when we decrease the silicon content then the tensile strength will be decreases, the minimum tensile strength was found in Aluminium alloy (1.5% of silicon) 120.87 MPa.

Conclusion:

The mechanical properties of aluminium alloy was calculated with variation of silicon content, the following conclusion are as followed.

- When we increase the silicon content then the melting point of aluminium alloy is decreases whereas fluidity will increases.
- The ultimate tensile strength will increases when we increase the silicon content.
- The Maximum ultimate tensile strength was 148.99 MPa in 6% of silicon content in aluminium alloy.
- The Minimum ultimate tensile strength was 120.87 MPa in 1.5% of silicon content in aluminium alloy.

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