# The Effect of Silicon Particulate on the Mechanical Properties and Microstructure of Aluminium Based Bearing Material (Al-6%Sn-0.35-1.40%Si)

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**Abstract** – The effect of different percentage of silicon on the ultimate tensile strength, energy absorbed, hardness and microstructure of aluminium bearing alloy was studied. Pure silicon powder was added to the aluminium bearing alloy (Al – 6%Sn) during casting to obtain different percentages of 0.35, 0.70, 1.05 & 1.40 of silicon for each of the composition. Samples were machined from the aluminium bearing alloy of composition (wt %); Al – 6%Sn (Control), Al – 6%Sn – 0.35%Si, Al – 6%Sn – 0.70%Si, Al – 6%Sn – 1.05%Si, Al – 6%Sn – 1.40%Si. From each composition of the aluminium bearing alloy five samples were machined and subjected to tensile test, impact test and hardness test. All the samples of the aluminium bearing alloy were taken and subjected to thorough metallographic samples preparation processes. The results obtained in this investigation shows that the aluminium bearing alloy with 0.35% Si gave a slight improvement in the ultimate tensile strength, energy absorbed and hardness value, the sample with 0.70% Si gave a great improvement in the ultimate tensile strength, energy absorbed and hardness value, 1.05% Si gave a greater improvement in the ultimate tensile strength, energy absorbed and hardness value, while 1.40% Si gave the highest ultimate tensile strength, absorbed and hardness value. In this work particulate method was used to hardening and strengthening the bearing material.

**Keywords** – aluminium, bearing material, elongation, energy absorbed, hardness, microstructure, silicon, tensile strength, tin.

## 1.0. Introduction

Aluminium is the most abundant metal and third most abundant element in the earth crust, after oxygen and silicon. It makes up about 8% by weight of the earth's solid crust, and not found free in nature. Bearings support moving parts, such as shafts and spindles, of a machine or mechanism. In general, a bearing application involves the sliding action of two materials against each other under a given load, speed, and environmental conditions. The bearing behavior of a particular material combination is determined by the system (chosen materials, surface roughness, lubricant, history of handling, environmental exposure) and stress factors (type of motion, sliding speed, movement pattern, surface pressure, temperature, loading time) [1]. Generally, bearing metals are cast alloys which contain hard particles of intermetallic compounds embedded in a softer matrix. The hard particles act as the bearing zones and the requirements for wear resistance and plasticity are both met by the combination of the soft matrix and hard particles. It is common in bearing alloys to have a primary $\alpha$ and a hard phase $\beta$ embedded in a eutectic structure [2]. In bearing failure, there are three usual limits to the lifetime or load capacity of a bearing material which are abrasion, fatigue and pressure [1]. Lubrication is very important in bearing materials; usually a thin film of lubricating oil separates the bearing and rotating shaft, and hence prevents critical metal – to – contact. There are some bearings that are self-lubricating. However, for bearings that have limited oiliness qualities (particularly the hard ones) lubrication by applying oil is normally desirable [1]. Since most bearing materials require a hard particle embedded in a soft matrix it is necessary to introduce ways for hardening and strengthening of the bearing material, like solid solution hardening, precipitation (or age) hardening, dispersion hardening, strengthening by grain refinement, strain hardening, particulate strengthening, phase transformation hardening and strain ageing [3].

## 2.0. Experimental Method

### 2.1. Collection of Materials

The materials used for this research which were aluminium scrap, tin ingot and pure silicon powder. The aluminium scrap was obtained from Northern Cable Company Limited (NOCACO) in Kaduna State, Nigeria, while the pure tin ingot was obtained from the National Metallurgical Development Centre (NMDC) in Jos, Plateau State, Nigeria and the silicon powder was obtained in Zaria, Kaduna State, Nigeria.

### 2.2. Melting and Casting

The melting and casting which was carried out in the foundry workshop of the Department of Metallurgical and Materials Engineering, ABU, Zaria, Kaduna State, Nigeria. The aluminium scrap were measured based on charge calculation and was put into the crucible and melted, then a measured amount of tin ingot was also added, after which silicon powder was applied and properly stirred before casting. The melt was then poured into the mould and

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allowed to solidify. The amount of silicon for each sample cast was varied for different composition of the casting, while the amount of tin remained constant and the aluminium was always the balance.

### 2.3. Machining of Samples

The bars which were 20mm in diameter and 400mm in length, were machined into tensile specimens, impact specimens, hardness specimens and metallography specimens from each bar of various composition.

### 2.4. Tensile Test

The tensile test was carried out on a Tensometer tensile testing machine, the tensile testing machine which had a lower and upper grip, was used to grip the samples and load was applied. The yield load, maximum load, and fracture load were all recorded for each sample. The tensile test showed both the elongation properties and reduction in cross – sectional area.

### 2.5. Impact Test

All the prepared impact samples were subjected to the Izod V – notch impact test, using Avery Pendulum impact testing machine with a striking energy capacity. The impact test was used to determine the amount of energy absorbed by each of the samples. The frame is of exceptional rigidity with Izod test fixtures attached directly to the machine frame so that no appreciable energy is absorbed by deflection of the clamps or the machine frame.

### 2.6. Hardness Test

All the prepared hardness samples were subjected to Rockwell hardness test using Indentec Universal hardness testing machine. The Rockwell hardness testing machine consists of a standard hardened steel ball of 1/16 inches which was pressed unto the surface of the sample by an applied load. The load was maintained on the sample for about 15 seconds and the average of three readings was taken for each sample. The indenter was inserted into the machine while the samples were cleaned using emery cloth to provide a lustrous surface. The samples were placed on the top of the elevating screw and screw was raised. As the screw moved up, the reflector threw the light on the surface of the test sample. A sharp view of the sample, showing the surface qualities then appeared on the ground glass screen. The diameter of indentation on the sample was measured using a low powered microscope. The indentation was repeated for three places on each sample.

### 2.7. Metallographic Sample Preparation

All the samples were taken and subjected to thorough metallographic sample preparation processes as outlined below.

1. Rough grinding of the samples were carried out successively on 60, 120 and 180 grits abrasive papers so that scratches were produced roughly at right angle to the initially existing scratches on the samples.
2. Fine grinding of the samples were carried out successively on 240, 400 and 600 grits abrasive papers using wet grinding method. During the fine grinding process, the samples were turned through angle $90^o$.
3. The ground samples were polished on a polymet polishing machine until the process scratch marks were removed.
4. Rough polishing: a little quantity of diamond powder (particle size about 6 microns) carried in the form of paste was placed on the nylon – covered surface of the rotating polishing wheel with considerable pressure and then moved around the wheel in the direction opposite to the rotation of the wheel to ensure a more uniform polishing action.
5. Fine polishing: This was carried out on the samples in order to remove fine scratches and very thin distorted layer remaining from the rough polishing stage. The polishing compound used was alumina ($Al_2O_3$) powder placed on the cloth – covered rotating wheel.
6. Etching: All the polished samples were etched using 2mls Hydroflouric acid, 5mls Nitric acid, 100mls Distilled water. The surfaces of the polished samples were rubbed gently with a cotton swab, wetted with the etchant. After the etching, the samples were again washed thoroughly and dried.

### 2.8. Microscopy

The samples were placed under the optical metallurgical microscope attached to a computer system, the microstructure of the samples were adjusted until the best view of the microstructure is obtained, then it is snapped and printed out. These were used to take the photomicrograph of the samples one after another until the photomicrographs of the samples were taken.

## 3.0. Results and Discussion

### 3.1. Mechanical Properties of Aluminium Bearing Alloy

The mechanical properties of the Aluminium bearing alloys shows significant improvement as the percentage of silicon increases in the alloy, as the amount of Si increases the ultimate tensile strength, toughness and hardness, while the percentage elongation decreases. This is because the aluminium bearing alloy has a tough case and the Si particles provide a hard core for the bearing alloy, so as the Si particle increases the hardness of the bearing alloy also increases and since the case is tough the amount of energy absorbed to the point of fracture increases, so its toughness increases. The ultimate tensile strength also increases, when the amount of Si particle increases, because this increases the stress at which plastic deformation takes place. But the percentage elongation which is a measure of ductility decreases, because ductility is a measure of the degree of plastic deformation that has been sustained at fracture, so as the amount of Si increases, the hardness also increases the alloy starts becoming a little brittle and the degree of plastic deformation been sustained at fracture decreases.

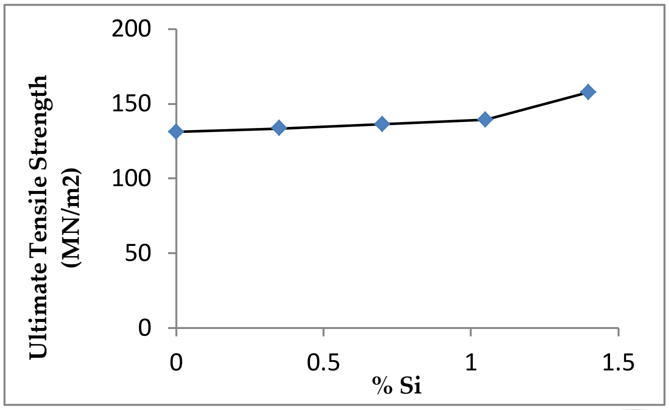


**Figure 1: Effect of Silicon on Ultimate Tensile Strength**

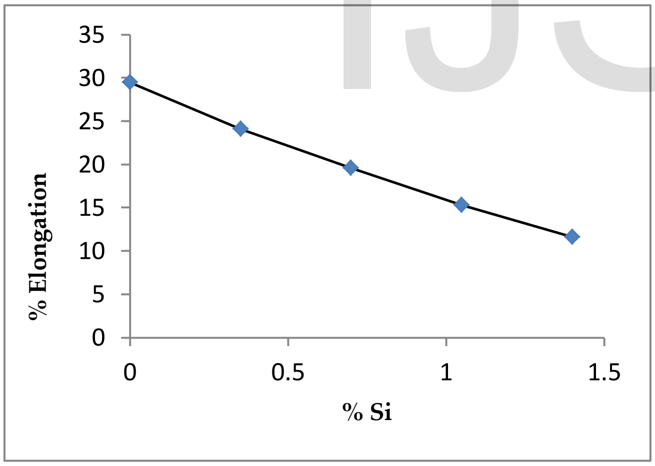


**Figure 2: Effect of Silicon on Percentage Elongation**

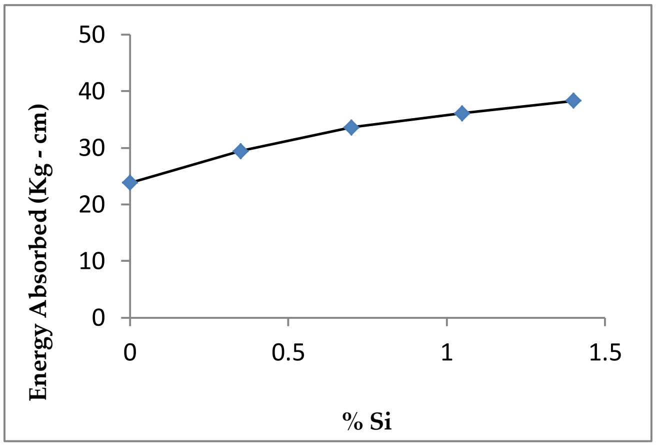


**Figure 3: Effect of Silicon on Toughness (Energy Absorbed)**

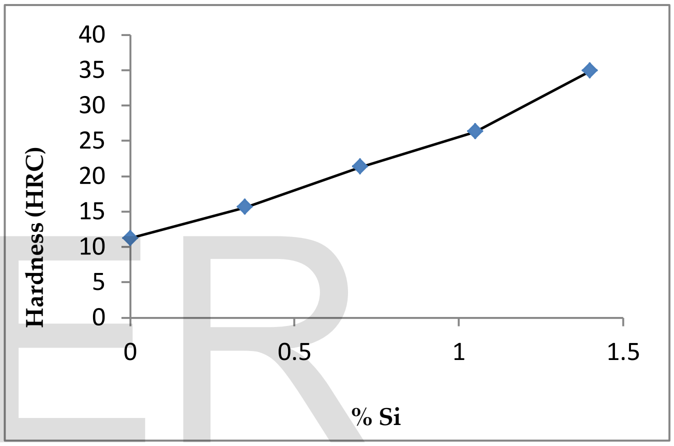
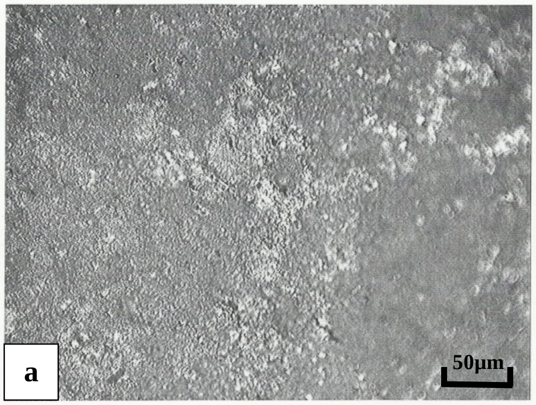


**Figure 4: Effect of Silicon on Hardness**

### 3.2. Microstructure of Aluminium Bearing Alloy

The microstructure of the aluminium bearing alloy varies from figure 5(a-e) as the amount of silicon is increased. The microstructure of the control sample with 0%Si shows the microstructure of light β (Sn) phase in dark α (Al) matrix, as the amount of Si increases from 0.35% Si to 1.40% Si nodules and flakes begin to form in the alloy, these also explains why the tensile strength increases, because the flakes serve as crack arrested which impedes the propagation of the cracks in the bearing alloy. The nodules tend to toughen the alloy.



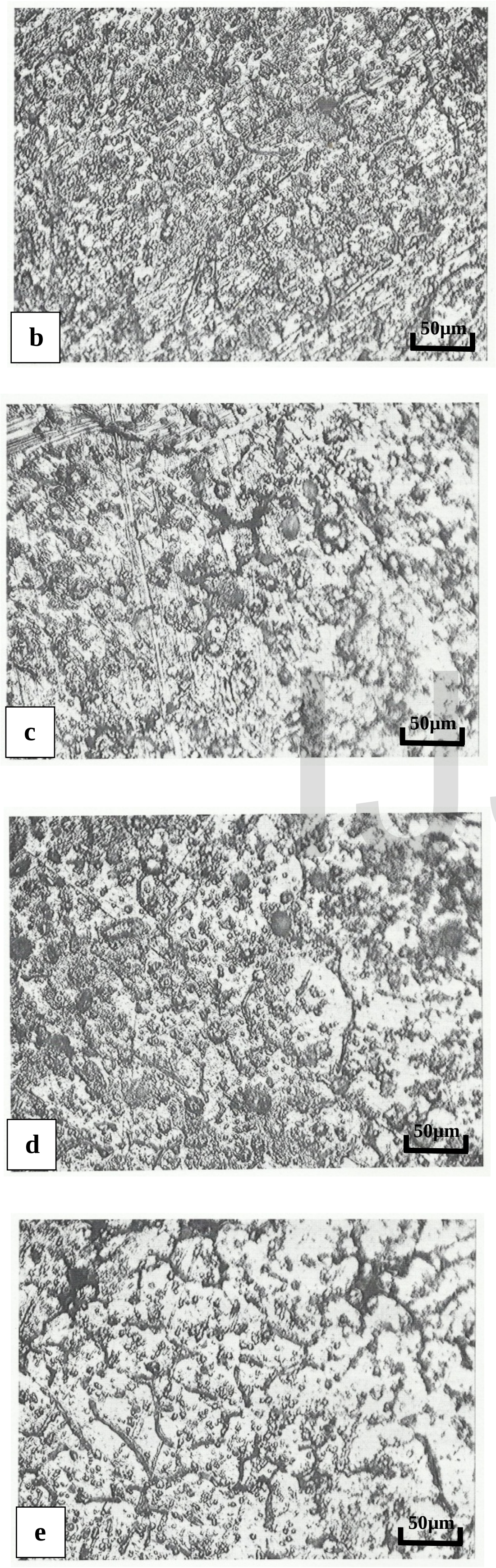


**Figure 5:** $\alpha$-Al matrix (dark), β-Sn (light) surrounding Si particles (noddles and flakes) in (a) 0% Si (b) 0.35%Si (c) 0.70%Si (d) 1.05%Si (e) 1.40%Si.

## Conclusion

The results obtained in this investigation showed that the aluminium bearing alloy with 0.35% Si gave a slight improvement in the ultimate tensile strength, energy absorbed and hardness value, the sample with 0.70% Si gave a great improvement in the ultimate tensile strength, energy absorbed and hardness value, 1.05% Si gave a greater improvement in the ultimate tensile strength, energy absorbed and hardness value, while 1.40% Si gave the highest ultimate tensile strength, absorbed and hardness value.

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