



A study on mechanical behaviours of newly developed aluminium-based alloy

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Abstract-This paper presents the study of different mechanical properties such as Hardness, Tensile strength, Impact strength, Flexural strength, Fatigue strength and Corrosion resistance of newly developed Aluminium- based alloys. The addition of Silicon and Copper will improve the property of the Aluminium alloy. The specimens were prepared with the help of Electric furnace using Stir casting method and the tests were conducted at atmospheric condition. The prepared specimen was subjected to special heat treatment T6 process of 540^o at 6 hours followed by quenching then cools the specimen for 3 hours in atmospheric condition. After that the annealing process is followed at a temperature of 150^o at 6 hours. The mechanical properties of Heat treated alloys were improved as compared to the as-cast condition. Also in this kind of alloys may be subjected to use in various applications like Engine bearings, cylinder liner, pistons etc.

Keywords-Hardness, Tensile strength, Impact strength, Fatigue strength and Corrosion resistance

I. INTRODUCTION

A. Definition of Alloy and Bearing

An alloy is a mixture or metallic solid solution composed of two or more elements. Complete solid solution alloys give single solid phase microstructure, while partial solutions give two or more phases that may or may not be homogeneous in distribution, depending on thermal (heat treatment) history. Alloys usually have different properties from those of the component elements. Alloy constituents are usually measured by mass. A bearing is any of various machine elements that constrain the relative motion between two or more parts to only the desired type of motion. This is typically to allow and promote free rotation around a fixed axis or free linear movement; it may also be to prevent any motion, such as by controlling the vectors of normal forces. Bearings may be classified broadly according to the motions they allow and according to their principle of operation, as well as by the directions of applied loads they can handle. The most sophisticated bearings, for the most demanding applications, are very expensive, highly precise devices, whose

manufacture involves some of the highest technology known to human kind. The main function of a rotating shaft is to transmit power from one end of the line to the other. It needs a good supports to ensure stability and frictionless rotation. The support for the shaft is known as bearing.

B. Literature Survey

Akira Ueno et al. revealed that the fatigue lives obtained in vacuum are always longer than that obtained in ambient air, because the fatigue crack initiated inside materials are cut off the air [1]. J Sikora et al. investigated the fatigue resistance of metal hydrodynamic journal bearings. The experimental investigation reveal that bearing lining fatigue resistance depends on, type of material, asymmetry of loading cycle, temperature, pressure fluctuation of oil film, and lubricants physico-chemical effects, especially influence of lubricants additives [2]. J Sikora et al. tested the Fatigue Strength limit of slide bearing materials and find out the value of critical tangential stresses in investigated bearings, corresponding to fatigue cracks using FEM [3].

M C Mwanza et al. experimentally investigated about the Microstructural characterisation of fatigue crack initiation in Al-based plain bearing alloys. The experimental investigation showed that Fatigue initiation occurs by decohesion at Si particles, and in the absence of Si particles decohesion occurs at Sn particles [4]. Q Y Wang et al. find out the Fatigue and Fracture Behaviour of Structural Al-Alloys Up to Very Long Life Regimes. The experimental results showed that the fatigue failure can occur beyond 10⁷ cycles and even at 10⁹ cycles and beyond. No endurance limit could be seen in the alloys until 10⁹ cycles. It is observed that significant interfacial void occurs in the two Al-alloys in early fatigue crack growth process [5].

G Shatil et al. have investigated Fracture toughness and fatigue crack growth tests and numerical simulations on 3PB specimens. This work showed that Stable crack growth region appeared in the ductile material until the crack approached the interface and continued in much faster rate of about an order of a magnitude in the brittle material [6].

A Burke-Veliz et al. have analyzed the Fatigue crack shielding and deflection in plain bearings under large-scale yielding. The study of crack propagation in multi-layered systems under three-point bending helps the identification of circumstances leading to path deflection and bifurcation [7]. R. Sadeler et al. have carried out four different microstructure feature produced by solution heat, then quenching in cold water, followed by aging. The heat treatment improves the rotating bending fatigue strength compared to as cast materials (non-treatment material) [8]. Joel Payne et al. reported the study of the initial stages of fatigue crack formation in the commercial aluminum alloy. It was found that all of the fatigue cracks emanated from cracked constituent particles, and that only the hard, i.e. iron-bearing, particles acted as effective crack initiation sites [9]. A Tauqir et al. investigated the causes of fatigue failure in the main bearing of an aero engine. Fatigue failure in the central main bearing (CMB) of the compressor shaft of an aero-engine resulted in an air-crash [10].

C. Mechanical Properties

Often materials are subject to forces (loads) when they are used. Mechanical engineers calculate those forces and material scientists how materials deform (elongate, compress, and twist) or break as a function of applied load, time, temperature, and other conditions. Materials scientists learn about these mechanical properties by testing materials. Results from the tests depend on the size and shape of material to be tested (specimen), how it is held, and the way of performing the test. That is why we use common procedures, or standards, which are published by the American Society for Testing and Materials (ASTM).

II. EXPERIMENTAL PROCEDURE

A. Material and heat treatment

Al, Si and Cu alloy produced by Stir casting has been used for the experiments. The chemical composition of the material is reported in Table 1. The specimen was subjected to special heat treatment T6 process of 5400 at 6 hours followed by quenching then cools the specimen for 3 hours in atmospheric condition. After that annealing of 1500 at 6 hours. Finally the experimental results were compared with the Al-Sn alloy.

B. Composition of Aluminium based alloys

Aluminium bearing alloys may be strengthened by addition of copper, silicon and Tin.

1) *Silicon (Si)*: Some of aluminium based bearing alloys contain silicon. Silicon has very high hardness and its inclusions distributed over the aluminium matrix serve as abrasive particles polishing the mating journal surface.

2) *Tin (Sn)*: Aluminium based bearing alloys commonly contain tin as a soft component. Tin is distributed in aluminium matrix as a separate phase in form of a reticular (network) structure along the edges of aluminium grains. Tin

imparts to the material anti-friction properties (compatibility, conformability, embedability).

3) *Copper (Cu)*: The aluminium-copper alloys typically contain 1.2% copper, with smaller additions of other elements. The introduction of copper to aluminium can also reduce ductility and corrosion resistance.

TABLE I
COMPOSITION OF ALUMINIUM ALLOY

Sn	Ci	Si	Al
22%	1.2%	3.3%	Balance

C. Experimental Test

Mechanical testing reveals the elastic and inelastic behavior of a material when force is applied. A mechanical test shows whether a material or part is suitable for its intended mechanical applications by measuring elasticity, tensile strength, elongation, hardness, fracture toughness, impact resistance, stress rupture, and fatigue limit. Mechanical testing plays an important role in evaluating fundamental properties of engineering materials as well as in developing new materials and in controlling the quality of materials for use in design and construction. As a result engineers have developed a number of experimental techniques for mechanical testing of engineering materials subjected to tension, compression, bending or torsion loading.

1) *Hardness test*: An indenter of known geometry and dimensions is impressed into the surface of the specimen by a known load. The size of the indentation made (as determined by measuring its depth, or area, depending on the test), provides an indication of the hardness of the material. The Brinell harness number is calculated by dividing the load applied by the surface area of the indentation.

$$BHN = \frac{F}{\frac{\pi}{2} D (D - \sqrt{D^2 - d^2})} \quad \text{-- (1)}$$

2) *Tensile Test*: Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to uni axial tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. A standars specimen of length 178*20*3 mm is required (Refer Figure 1). It can be either injection molded or cut from a flat sheet.

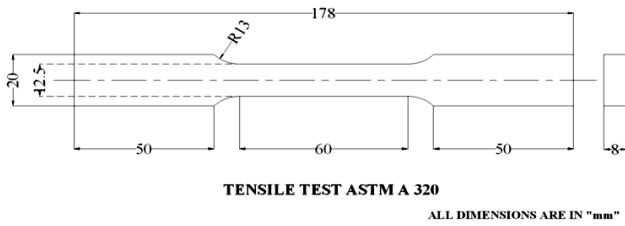


Fig 1 Dimension of Tensile Test Specimen

3) *Flexural Test:* Most commonly the specimen lies on a support span and the load is applied to the center by the loading nose producing three point bending at a specified rate. The parameters for this test are the support span, the speed of the loading, and the maximum deflection for the test. These parameters are based on the test specimen thickness and are defined differently by ASTM and ISO. For ASTM D790, the test is stopped when the specimen reaches 5% deflection or the specimen breaks before 5%.

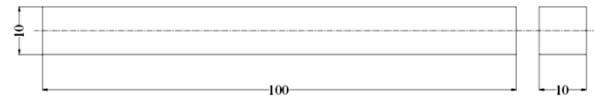


Fig 2 Dimension of Impact Test Specimen

4) *Impact test:* Test for determining toughness, or the tendency of a material to resist breaking on being subjected to sudden shock. It involves notching a bar on the test specimen, clamping one end (in a cantilever beam configuration) and striking the other end so it breaks off. The standard specimen for ASTM used in this test is 64 x 13 x 3 as shown in figure 3.

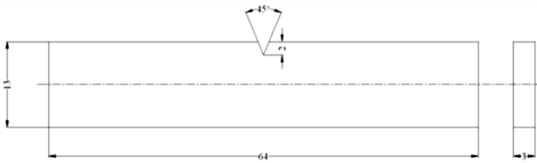


Fig 3 Dimension of Impact Test Specimen

5) *Corrosion test:* The pre-treated plates are weighed accurately and the weight is taken as W_1 . Then the plates are completely immersed in the corrosive media for a known time (T) with proper labelling in the respective beakers. After the stipulated period of time is over, the specimens are removed, washed well using running water, dried and weighed the reduced weight is considered as W_2 . the corrosion rate is calculated from the weight loss ($W_1 - W_2$) of the specimens using the given formula:

$$\text{Corrosion Rate (CR)} = \frac{535 \times W}{D \times A \times T} \text{ mmpy}$$

Where, W - Weight loss of the specimen in mg,
 D - Density of the specimen in g/cm^3
 A - Area of the specimen in sq inch
 T - Exposure time in hours.

A specimen immersed in HCL helps to conduct the corrosion test is given in Refer Figure 4.



Fig 4 Concentration HCl

6) *Fatigue test:* A method for determining the behavior of materials under fluctuating loads. A specified mean load (which may be zero) and an alternating load are applied to a specimen and the number of cycles required to produce failure (fatigue life) is recorded. Generally, the test is repeated with identical specimens and various fluctuating loads. Loads may be applied axially, in torsion, or in flexure. Depending on amplitude of the mean and cyclic load, net stress in the specimen may be in one direction through the loading cycle, or may reverse direction. A standard specimen used for this test, as per ASTM is 64 x 13 x 3 mm (Refer Figure 5).

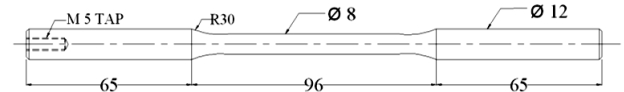


Fig 5 Dimension of Fatigue Test Specimen

III. TEST RESULTS

A. Tensile Test

The Universal Testing Machine (UTM) helps to find the tensile testing of the developed specimen. The Heat Treated alloy gives better results than the non-heat treated alloys.

TABLE III
TENSILE TEST RESULTS

Sample	CS Area	Peak Load [N]	%Elongation	Stress [N/mm ²]	Strain Break	Break Load [N]
HT	160	7689.598	5.410	28.832	0.017	1626.4
NHT	160	5603.031	2.690	21.013	0.012	416.189

B. Flexural Test

The Heat Treated alloy gives more hardness values than the non-heat treated alloys.

TABLE IIIII
FLEXURAL TEST RESULTS

Sample	CS Area	Peak Load [N]	Break Load [N]	Flexural Strength (MPa)	Flexural Modulus (GPa)
HT	100	952.090	47.667	78.547	8627.725
NHT	100	1177.406	59.733	97.136	7005.673

C. Impact Test

The Heat Treated alloy gives more impact values than the non-heat treated alloys

TABLE IVV
IMPACT TEST RESULTS

Sample	Impact Values
HT	3.5
NHT	3.5

D. Corrosion Test

The Heat Treated alloy gives better results than the non-heat treated alloys.

TABLE V
CORROSION TEST RESULTS

Day	Weight Loss, ml	
	HT	NHT
1	3.564	3.769
2	3.468	3.667
3	3.371	3.589
4	3.359	3.570
5	3.346	3.478

E. Hardness Test

The Brinell hardness test method consists of indenting the test material with a 10 mm diameter hardened steel or carbide ball subjected to a load of 3000 kg. For softer materials the load can be reduced to 1500 kg or 500 kg to avoid excessive indentation. The Heat Treated alloy gives more hardness values than the non-heat treated alloys.

TABLE VI
HARDNESS TEST RESULTS

Sample	BHN
HT	39
NHT	32

F. Fatigue Test

Two swiveling bodies are mounted in their brackets and fixed over the base. These bodies contain within them the hollow shaft assemblies. The hollow shaft assembly consists of the hollow shaft, collets, clamping cum, loosening rings, lock nut, and bearings. These RH and LH assemblies hold and grip the specimen. The clamping cum loosening ring tightens. The rotation preventing assembly consisting of locking ring, locking rod and spring helps in preventing the rotation of hollow shaft assembly while loosening the specimen. The motor inside the base drives the RH hollow shaft assembly through belt and flexible shaft. The pulleys are so selected that

the specimen is rotated at 4200 rpm. The Heat Treated alloy gives better results than the non-heat treated alloys.

TABLE VII
FATIGUE TEST RESULTS

Sample	No of cycles
HT	10^6
NHT	10^5

IV. CONCLUSIONS

The mechanical properties of aluminum alloy was investigated and compared with non heat treated alloy. The results indicate that addition of silicon and copper to the existing aluminium alloy improves the mechanical properties. The heat treatment followed by the Quenching and Annealing also confirmed its efficiency in giving a remarkable improvement of mechanical properties.

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