# WEAR STUDIES OF Al-Si ALLOYS

A THESIS IN PARTIAL FULFILMENTS OF REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF

## Bachelor of Technology

Submitted to

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

BY

**Souvik Sen & Deepak Kumar Behera**

**(110mm0477) (110mm0608)**

DEPARTMENT OF METALLURGICAL & MATERIALS ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA – 769008

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# CERTIFICATE

*This is to certify that the Thesis entitled "Wear Studies of Al-Si Alloys" submitted by Souvik Sen (Roll No.110MM0477) & Deepak Kumar Behera (Roll No.110MM0608), Department of Metallurgical and Materials Engineering, National Institute of Technology, Rourkela, as a partial fulfillment of requirements for the award of the Degree of Bachelor Of Technology has been carried out under my supervision and has not been submitted elsewhere fancy award of any degree.*

**Prof. S.C. Mishra**

**Department of Metallurgical**

**And Materials Engineering**

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Date: 7th May, 2014
Place: Rourkela
Souvik Sen (110mm0477)
Deepak Kumar Behara (110mm0608)

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# ABSTRACT

There are many properties of Aluminium-Silicon alloys such as high wear resistance, light weight, low coefficient of thermal expansion and high strength to weight ratio, that makes it suitable for many industries. In recent years, it has gained huge acceptance in automotive industries, as its use results in fuel saving, hence cost saving. These advancements make the study of properties of Al-Si alloys important. In the present study, wear behaviour of Al-Si alloys were studied. Aluminium containing 10 weight % of Silicon was synthesized using casting method. The microstructure showed the presence of Proeutectic silicon. Wear behaviour was studied by using computerized pin on disc wear testing machine. The abrasion of the alloy increased as sliding distance and time increased. The crack morphology of the worn surfaces were analysed using stereo microscope.

**Keywords**: Al-Si alloys, casting, wear, microstructure

# CHAPTER – 1

# INTRODUCTION

## 1.1 Alloy

An alloy is a solution which has metal-like characteristics. It is formed by blend of two or more elements with least one of them is metal (which is the major contributor).

The metallic bond must dominate in its crystal structure. The metallic atoms must dominate in its chemical composition. The properties may vary slightly to a large extent from the contributing elements. Alloys are mostly used for the purpose where pure components are not a viable option. For example, small amount of carbon present in steel increases the hardness of the wrought form of iron. Some physical properties, such as conductivity, density and appearance may not vary greatly, but mechanical properties such as strength, toughness and hardness may change rapidly with change in alloy content. In many a case, the alloying particles act as moon dust, in the sense that a small addition can bring in magical properties. The benefits of alloy addition also depends upon the treatment used for manufacturing the alloy.

## 1.2 Aluminium alloys

Aluminium alloys have gained wide area of usage in automotive industries, in recent years. As Aluminium alloys have high specific modulus and high specific toughness, therefore these alloys are used in automotive components for fuel saving, and thus improving cost and economy. The alloying elements of Al are generally Cu, Mg, Si, and Zn etc. Surfaces of Aluminium alloys forms a shielding layer of Aluminium oxide, thus preventing the Aluminium present in the core from corrosion. Aluminium alloys are given nomenclature such as 4xxx, 5xxx and 6xxx series where the numbers such as 4 represents the major alloying element, Si. Due to these reasons, these alloys were tested and studied in scientific circles.

## 1.3 Designation of Aluminium alloys

Major alloying element is the basis for classifying the Aluminium allioys. The classification of the Aluminium alloys are done according to the Aluminium Association Wrought Alloy Designation System which basically consists of four numerical digits[3].

**Table 1.1: Designation of aluminium alloys and their applications**

| Alloy | Main alloying element | Applications |
|---|---|---|
| 1xxx | It has mostly pure Aluminium with no major alloying addition. | Chemical and Electrical Industry |
| 2xxx | Cu(Copper) | Components of Aircraft |
| 3xxx | Mn(Manganese) | Application in architecture |
| 4xxx | Si(Silicon) | Automobile Parts and Welding Rods |
| 5xxx | Mg(Magnesium) | Marine industry such as Boat Hulls |
| 6xxx | Mg and Si | Architectural Industry such as extrusions |
| 7xxx | Zn(Zinc) | Components of Aircraft |
| 8xxx | Other elements such as Iron | |
| 9xxx | Those which are mentioned above | |

## 1.4 Properties of Aluminium alloys

A broad variety of mechanical and physical properties can be procured from wrought Aluminium. The different properties are:

1) Aluminium is a light metal having a density of 2.7g/ml which is almost a third of density of steel.
2) Aluminium prevents advancing oxidation and corrosion by formation of a shielding oxide layer on its surface which prevents the core from coming to direct contact with the environment.
3) Aluminium alloys exhibit excellent thermal and electrical properties. It has wide use in electrical industry as the thermal conductivity is twice that of the Cu.

## 1.5 Aluminium-Silicon alloy

Al-Si alloys are of great importance to many industries as they impart high wear resistance, high strength to weight ratio, low coefficient of thermal expansion low density etc. Silicon exhibits low shrinkage and high fluidity, that gives these alloys good weldability and castability. Al-Si alloys are given a nomenclature of 4xxx alloys according to the Aluminium Association Wrought Alloy Designation System. The major features of the Al-Si alloys are:

a. They are moderately heat treatable.
b. They show good flow characterestics.
c. They are easily weldable.

The two most important uses of the 4xxx series Al-Si alloys are for forging and weld filler alloy. These applications are feasible due to the good flow characteristics given by relatively high silicon amount.

Effects of Si in the Al-Si alloys can be summed as[4]:

i. Silicon reduces thermal expansion.
ii. Silicon has a very low effect on magnetic susceptibility and reduces it by a very low amount.
iii. Lattice Parameter decreases on adding Si.
iv. Silicon is hard and therefore the machinabilty of these alloys deteriorates.

Although many investigations exist in literature and based on the above discussion, it is evident that there is enough scope for further research of Al-Si alloys especially their mechanical properties. Therefore the objectives of this study are;

i. To study of their microstructure.
ii. To study of their mechanical properties like hardness
iii. To study the wear behaviour.
iv. To study surface roughness.
v. To study crack morphology.
vi. To study effect of age hardening on wear.

# CHAPTER – 2

# LITERATURE REVIEW

## 2.1 Introduction

Aluminium alloys, are gaining vast industrial significance because of their undischarged combination of physical, mechanical, and wear resistance properties over its base alloys. They have high specific strength, high wear and abrasion resistance, better high temperature strength, high stiffness, improved damping capacity and low thermal expansion coefficient. Aluminium alloy with 10 wt% SiC particle reinforced composite offers same mechanical properties but higher thermal conductivity and specific heat than cast iron. As a result, frictional heating is found to be substantially less in these alloys than that of cast irons. This contributes to their use in engineering and automobile sectors excessively, where wear and tear are the very major problems. Some of the components are pistons, connecting rods and cylinder heads for automobile and impellers, turbine blade, agitators, vortex finder, pump inlet, in mining and marine sectors[5].

## 2.2 Aluminium-Silicon Alloys

### 2.2.1 Introduction

Alluminium alloys are distinguished according to their major alloying element. Silicon is the main alloying element for the 4xxx group. It give good casting properties to the alloy by decreasing its viscosity. It reduces melting temperature of the alloy, decreases shrinkage during solidification. Also it is very inexpensive for a raw material.

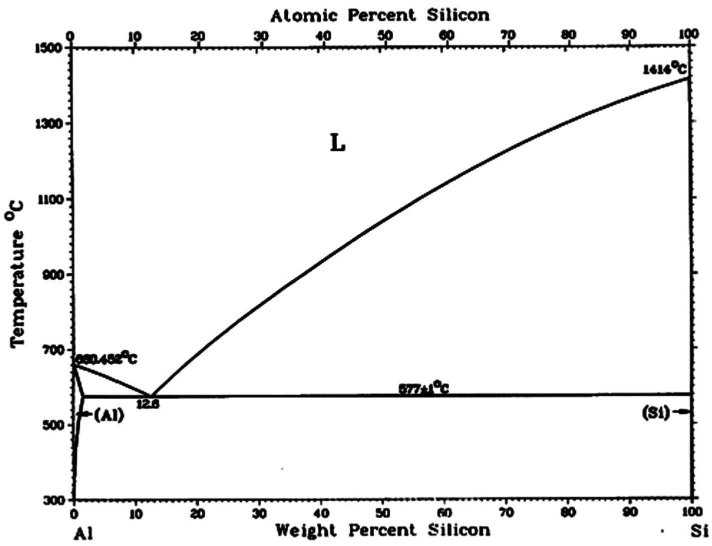
Silicon has low density (2.34 g/cm$^3$), which can be a advantage by reducing component's total weight. Si has very low solubility in Al; therefore it precipitates as pure silicon, hard and hence helps in improving abrasion resistance. Al-Si alloys form an eutectic at 12.6 wt% silicon, and at a temperature of 577°C.

### 2.2.2 Phase Diagram

Aluminium-Silicon is a basic binary eutectic system with limited solubility of aluminium in silicon. There is only one invariant reaction in this diagram, namely

$L \rightarrow \alpha + \beta$ (eutectic)

In above equation, L is liquid phase, while α is predominant aluminium, and β predominant silicon. The eutectic reaction occurs at a silicon level of 12.6 wt% at 577°C temperature.




Depending on Silicon weight percentage, the Aluminium-Silicon alloy systems can be divided into 3 major categories:

i. Hypo eutectic ( <12 weight % Silicon )

ii. Eutectic ( 12-13 weight % Silicon )

iii. Hyper eutectic ( 14-25 weight % Silicon )

### 2.2.3 Uses of Al-Si alloys

Al-Si alloys are used in the manufacture of vehicles cover, chassis, power trains and air conditioning. Aluminium castings are used in various automobile parts. Engine block, one of the heavy parts made of cast iron is being switched to aluminum that results in weight reduction. In automotive power trains, aluminium castings are used almost for 100% of the pistons, 75% of the cylinder heads, 85% of the intake manifolds and transmission. For chassis applications, Al-Si castings have been used for 40% of the wheels and for brake components, brackets, suspension, steering components and instrument panels.

Forged wheels are used where loading conditions are very extreme and where better mechanical properties is needed. Aluminium alloys have also found extensive application in heat exchangers.

Aluminium - Silicon alloys are important for many commercial-grade automotive applications due to their unique properties. Al-Si casting alloy are the most versatile among all general foundry cast alloys for the production of pistons used in automotive engines.

Commercial uses for hypereutectic alloys are comparatively limited because these are the most difficult Al alloys to cast and machine due to the high Si contents. Once high Si content is alloyed into Al, it adds a large amount of heat capacity that must be removed from the alloy to solidify it during the casting operation. Major variation in the sizes of the primary Si particles can be found between different areas of the cast structure, causing significant deviation in the mechanical properties for the specimen. The primary crystals of Si must be refined so as to accomplish better hardness and wear resistance. Due to these reasons, hypereutectic alloys are not very cost-effective to fabricate because they have a broad range of solidification that results in poor castability and requires extra foundry processes to control the microstructure and the high heat of fusion.

On the other hand, the use of hypo-eutectic and eutectic alloys is widespread in many industries, because they are:

a. more efficient to produce by casting
b. simpler to control the cast parameters
c. easier to machine than hyper eutectic.

But, many of them aren’t suitable for high temperature applications, like automotive field. Because the tensile strength is not as high as expected in the temperature range of 250°C - 400°C [9].

### 2.2.4 Microstructure

Binary Al-Si alloys, in the unmodified state, near to the eutectic composition exhibit lamellar or acicular eutectic Si, in the form of large plates with sharp edges and sides. Al-Si alloys that contain more than 12% Silicon show a hyper-eutectic microstructure normally containing PSP (primary silicon phase) in a eutectic matrix. Cast eutectic alloys having coarse acicular silicon show low ductility and low strength because of the course plate-like structure of the Silicon phase leading to untimely crack initiation and fracture during tension. Similarly, the PSPs in normal hypereutectic alloys are usually very coarse and impart poor physical and mechanical properties to these Al-Si alloys. Therefore, alloys with a predominantly eutectic structure should be altered to ensure adequate mechanical strength and suitable ductility. It is widely accepted that Group IA & IIA elements are effective Al - Si eutectic modifiers; only Na and Sr, however, have been used extensively in commercial-grade production of these Al-Si alloys. Refinement of PSPs (primary silicon particles) is usually achieved by addition of phosphorous to the melt. The rare earth metals are also capable in modifying eutectic structure of cast aluminium-silicon alloys[10]. Fig. 2.2 to Fig. 2.7 show microstructures of different Al-Si alloys.

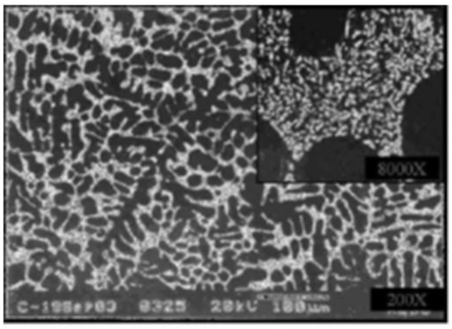



Fig 2.2 Microstructure of Al-7% Si[11]

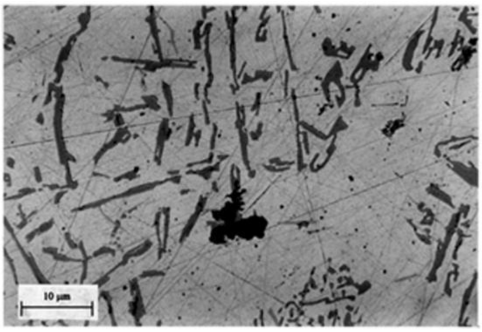



Fig 2.3 Microstructure of Al-12% Si[6]

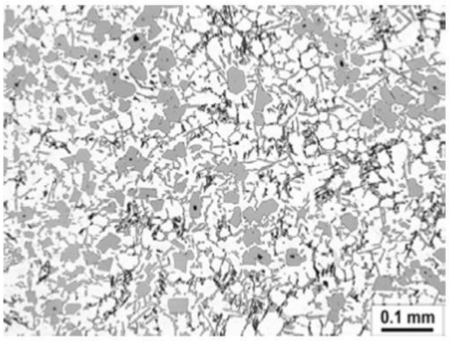



Fig 2.4 Microstructure of Al-16% Si[12]

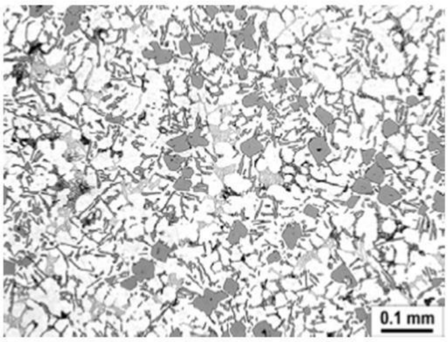



Fig 2.5 Microstructure of Al-18% Si[12]

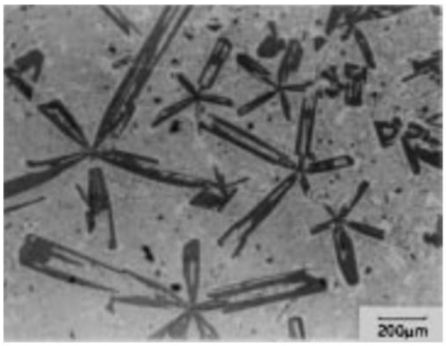



Fig 2.6 Microstructure of Al-21% Si[10]

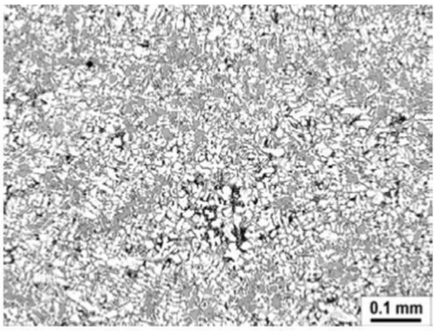



Fig 2.7 Microstructure of Al-22% Si[12]

### 2.2.5 Wear Behavior

Study of wear behavior has very much importance in various engineering and automobile industries because wear and tear of components is the major problem of such industries. Sliding wear behavior and abrasive wear behavior of Aluminium-alloys have been studied by many investigators. According to their reports, wear and abrasion resistance of Al-alloy is significantly higher than their base alloys. The hard disperroids protect the surface from the abrasives by decreasing the penetration depth of the abrasives and the contact between the abrasive and the matrix. On the other hand, some investigators have reported changeover of wear behavior of alloys which was reliant on applied load and abrasive size. Also, it is apparent from the literature about wear that the wear surface and subsurface experience plastic deformation. This deformation becomes very severe when the abrasives size is coarser and higher applied load. The wear behavior of an alloy depends upon material characteristics like shape, size, distribution and volume fraction of the disperrsoids and experimental parameters like abrasive size and applied load. It has been observed that wear and abrasion resistance of an alloy increases with rise in volume fraction, size of disperrsoids. One of the important factors of improvement in wear and abrasion resistance is increase in the hardness of Al-alloy, due to addition of the hard dispersoids and better protection of matrix from destructive action of abrasive as the mfp (mean free path ) between the Silicon Carbide particles is decrease with increase in volume fraction of the SiC particles. Several investigators have proposed that wear and abrasion resistance of a material also depends on the ductility and toughness. Reinforcement of $Al_2O_3$ particles in aluminium alloy improves the abrasive wear of the matrix. Reinforcement of coarse particle shows better wear resistance[5].

Alpas et al.[15] investigated wear mechanism in eutectic Al Si alloys, tested against hard steel counter face and observed that advancement of damage event usually comprised of following steps:

a) Wear of top surfaces of the Si particles by counter face.

b) Embedding of Si particles into aluminium matrix.

c) Plastic deformation of aluminium causing formation of aluminium pile-ups adjacent to sunken-in Si particles.

d) Wear of elevated portions of aluminium plateaus by the counter face.

The following graphs obtained from the tests by Das et al.[5] show the variation of wear rate of Al alloy, as a function of d (sliding distance) under different applied loads.

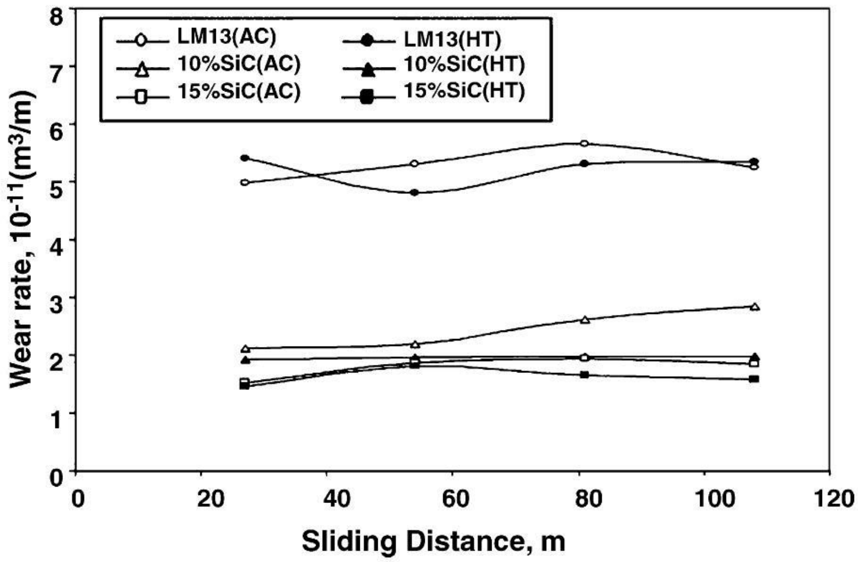



**Fig. 2.8 Wear rate Vs sliding distance of an Al alloy (applied load: 1N)**

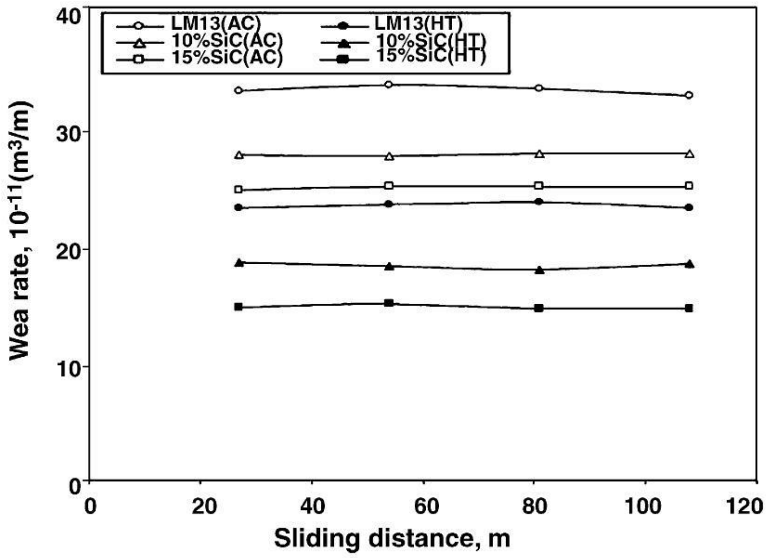



**Fig. 2.9 Wear rate of Al alloy as a function of sliding distance (applied load: 7N)**

## 2.2.6 Wear Mechanism

Wear processes may be assorted into different types based on the type of load and materials involved, for e.g., fretting wear, abrasive wear, sliding wear and cavitation. Wear can be caused by number of mechanisms. But the following four are especially important:

• Adhesion

• Abrasion

• Fatigue wear

• Corrosive wear

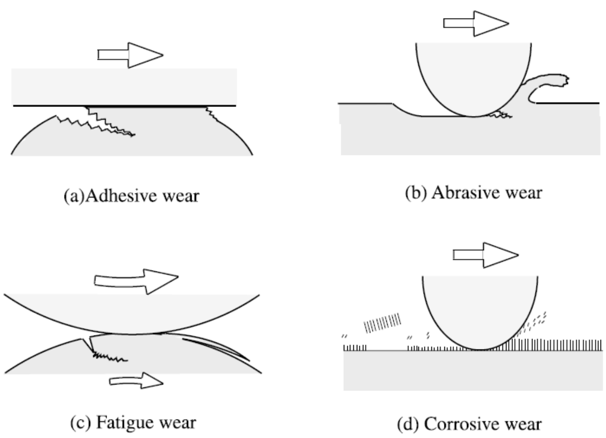



**Fig 2.10 Schematic images of four represented wear modes [ref wear m]**

*Abrasive Wear*

It occurs when a solid object is loaded against the particles of material which have hardness equal or greater than that of the object. Even if the bulk of a material is very soft, it may still cause abrasive wear due to presence of hard particles

.

## Mechanisms of Abrasive Wear

The first mechanism shown in Figure 2.11a, cutting, represents classic model, where a hard asperity or sharp grit cuts the soft surface. The material that is cut is removed as wear debris. When the material is brittle, for e.g. ceramic material, fracture of the worn surface may occur (fig 2.11b). wear debris is formed as a result of the  crack convergence.

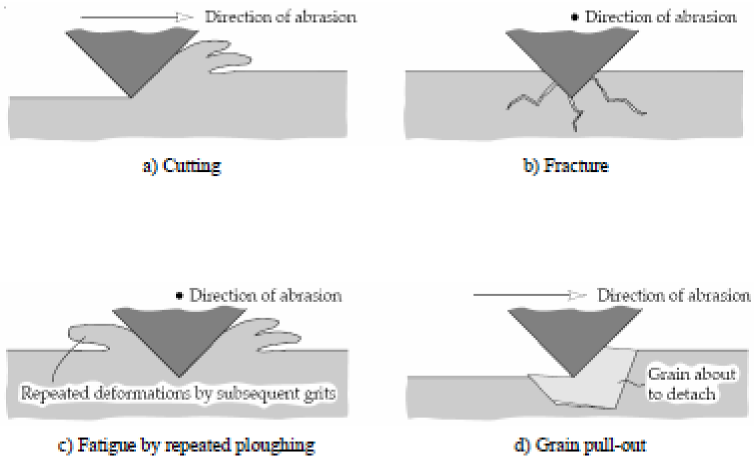



**Figure 2.11 Mechanisms of abrasive wear: microcutting, fracture, fatigue and grain pull-out**

When a ductile material is subjected to abrasion by blunt grit, cutting is unlikely and worn surface is subjected to repeated deformation (Figure 2.11c). Here, wear debris is formed as a result of surface fatigue. Figure 2.11d  shows grain pull-out. This mechanism is mainly applicable to ceramics; where grain boundary is comparatively weak. Wear debris is due to loss of entire grain.

## Modes of Abrasive Wear

The way the grits pass over the worn surface determines the nature of abrasive wear. Nature of the abrasive wear is determined by the way the grits pass on the worn surface. The literature talks of two modes of abrasivewear:

· two-body wear and

· three-body wear.

Two-body type wear can be exemplified as action of sand-paper on a surface. Hard asperities or strictly held grits pass over the surface like cutting tool. In three-body type wear, grits are free to roll and slide over the surface as they are not held in a rigid manner. The two-body and three-body mode of an abrasive wear are schematically illustrated in Figure 2.12.

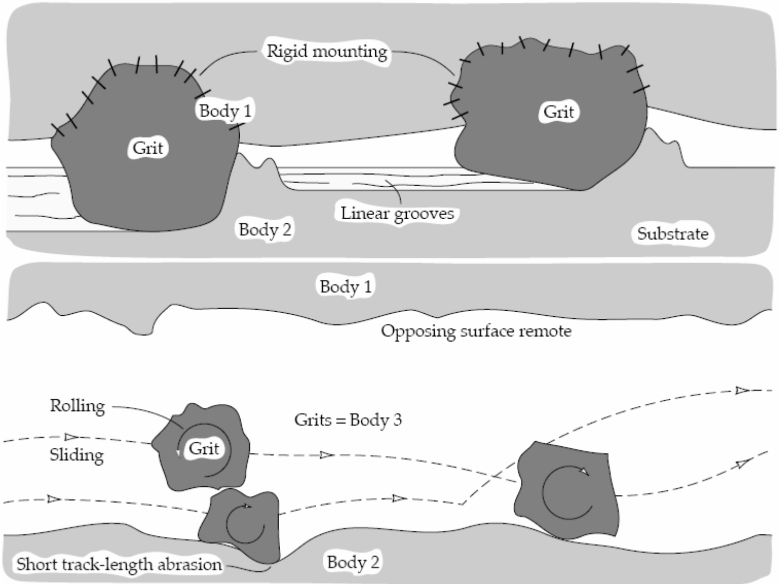



Figure 2.12: Modes of abrasive wear

Until recently, it was thought that these two modes are very similar, however, some very significant difference between these have been revealed by investigators [7]. It was found that three-body type wear is 10 times slower than the three-body type wear, for it has to compete with other mechanism like adhesive wear [8]

# CHAPTER – 3

# EXPERIMENTAL

## 3.1 Introduction

An Aluminium-10% silicon alloyblock of dimension 100mm x 100mm x 30mm were preparedby stir casting route in an induction heating furnace. Three cylindrical samples of diameter 10mm and height of 30 mm were cut from the block using a highly calibrated lathe machine. One of the sample was then polished to reveal the microstructure of the alloy. For this, stereo microscope was used. Wear behaviour of these samples were studied by conducting several wear tests on computerized Ducom friction and wear monitor pin on-disc wear test machine. The microstructures of the damaged/weared samples and of the crack morphology of the surfaces were observed under stereoscope.Profilometric studies were done to study the surface roughness.Age hardening of the samples was done at 200 C for time intervals of 4, 6 and 9 hours. The hardness was measured with the Vickers hardness testing machine. The following gives a detailed overview of the steps taken for different tests.

## 3.2 Dimensioning

3 cylindrical samples were cut from the block using the lathe machine. The dimensions of the cut samples were 10mm in diameter and 30mm in height.

## 3.3 Polishing

One of the sample was polished on one side to reveal the microstructure. Mechanical polishing was done using emery papers in the sequence of 1/0, 2/0, 3/0, and 4/0. After mechanically polishing the sample, cloth polishing using a 6 micrometer diamond slurry was done. After obtaining a mirror finish polishing of the sample, the sample was etched and was sent for the stereo microscopy.

## 3.4 Stereo Microscopy

The **stereo microscope** is a type of optical microscope and does not uses transmitted light instead uses light reflected from the surface of an object. The instrument uses two different optical paths with different objective and eyepieces to give different angles to the right and left eyes. This arrangement gives a 3-D visualization of the sample being tested. The difference between the light microscope and stereo microscope is that stereo microscope uses reflected light where as light microscope uses transmitted. The reflected light allows experimentation on specimens that would otherwise be too opaque or too thick for microscopy.

Microstructures of the alloy samples were observed under computerized stereo microscope.The Al-Si samples were mechanically polished upto mirror finishing and etched before the examination. Characterization is done in etched conditions. Etching was done using the Keller's reagent. The micrographs of the samples were obtained.

The same stereo microscope was used for crack morphology of the damaged samples as well.

**Figure 3.1: Stereo microscope of Physical Metallugy Lab, NIT Rourkela**

## 3.6 Wear test

Computerized Ducom friction and wear monitor uses the pin on disc wear test machine for the wear testing. (Model: DUCOM Wear and Friction Monitor, TR-20-M100, Bangalore, India). The disc which rotates is made of high carbon, quenched and tempered steel of diameter 120 mm and hardness of 70 HRC. The Al-10%Si samples were held stationary and the normal load is applied via a lever mechanism. The tests were done by varying one among the below mentioned parameters and keeping the other parameters constants:

i. applied load
ii. sliding speed
iii. sliding distance

No lubricant is used as test is carried out in dry conditions. The samples were weighed at regular intervals to measure weight loss. It was under careful examiniation that the specimens wearing in the test are continuously cleaned with woollen cloth so as to avoid the snaring of wear debris and to achieve uniformity in experiential procedure. Stereo microscope was used to analyse the crack morphology of the worn surfaces of sample.

**Fig 3.2Ducom friction and wear monitor pin on disc wear test machine**

Fig 3.3 Full view of Ducom friction and wear monitor

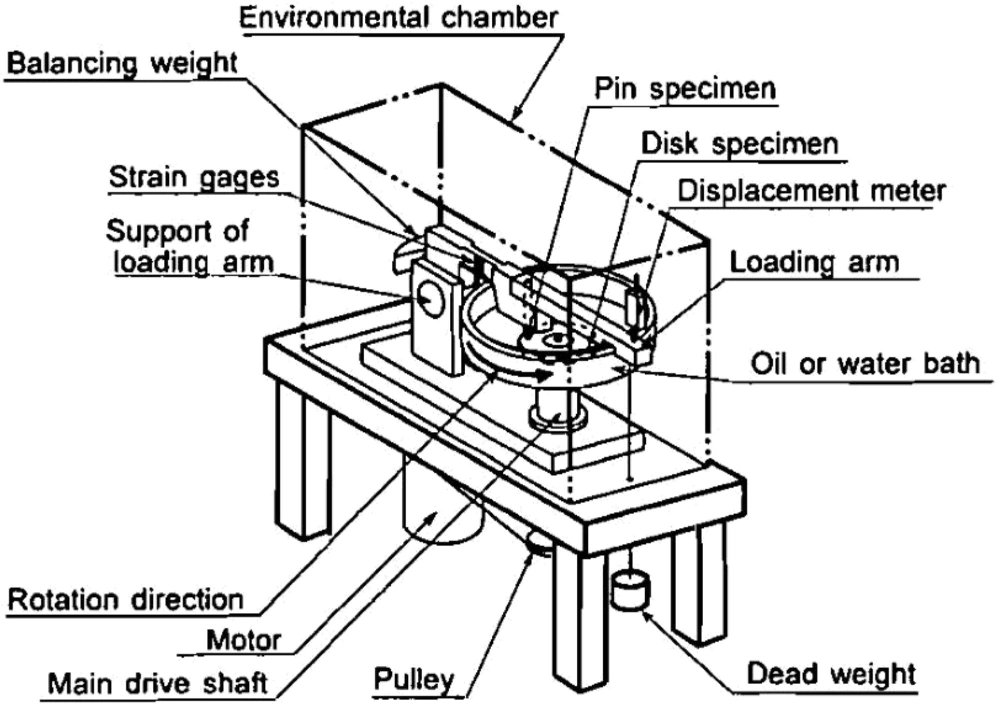



**Figure 3.4: Pin-on-disk type friction and wear apparatus[16**

## 3.7 Profilometer: Profilometer was used to study surface roughness.


Figure 3.5: Stylus ProfilometerVeecoDektat, Electrometallugy Lab, NIT Rourkela

### Introduction

Stylus profilometers are basically used in industries and research work to measure surface finish. The Profilometer have been in use in research and industries for a very long time. Originally an amplified plot of the surface profile was generated with some average parameters such as Ra. These parameters were obtained by means of a suitable meter and a simple electronic circuit. By the end of 1970 digital computers were added, and the data acquisition system revolutionized. A large varieties of data were obtained upon digitization.

### Key elements and Schematic diagram of the data acquisition system.

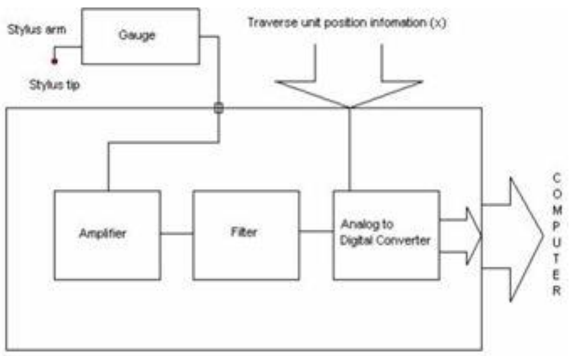



Figure 3.6: Schematic Representation of Profilometer

The basic component of data acquisition system is schematically shown in fig 3.7.

### Stylus

One of the most basic component in stylus Profilometer is the stylus, a tip which actually grazes the surface and act as a sensor. It acts in the same as skin, eyes etc as interface between the outer environment and the brain.  Stylus tip material, form, size and force are the important parameters in this case.

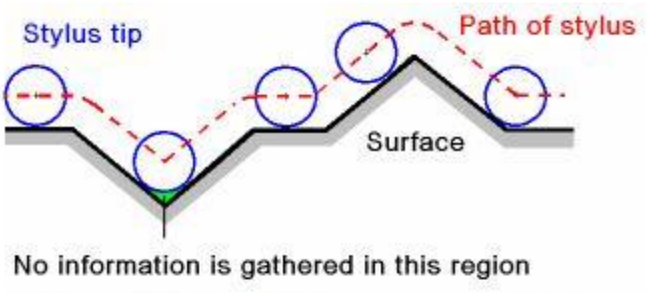



**Figure 3.7: Path of stylus running over a surface**

### Gauge

The interface between the stylus and the inner electronics is known as gauge in technical terms. Gauge contains some crucial electronics that controls the tracking force and sends a feedback as a result of any changes in roughness, that helps the stylus tip to move over the surface without damaging itself.

### Electronics

The gauge gives an output that amplifies and demodulates the electronics signals. It then converts the digital signal to user comprehensible language and stores the result for analysis.

# CHAPTER – 4

# RESULTS AND DISCUSSION

## 4.1 Introduction

Different tests like macrohardness test, wear test, stereo micrographs and profilometric studies on Al-Si alloys were carried out. The results obtained from these tests are reported analysed and discussed further in this chapter.

## 4.2 Microstructure

Microstructure obtained from computerised stereomicroscope are shown in fig 4.1 for Al-10% Si under the magnification of 50x.

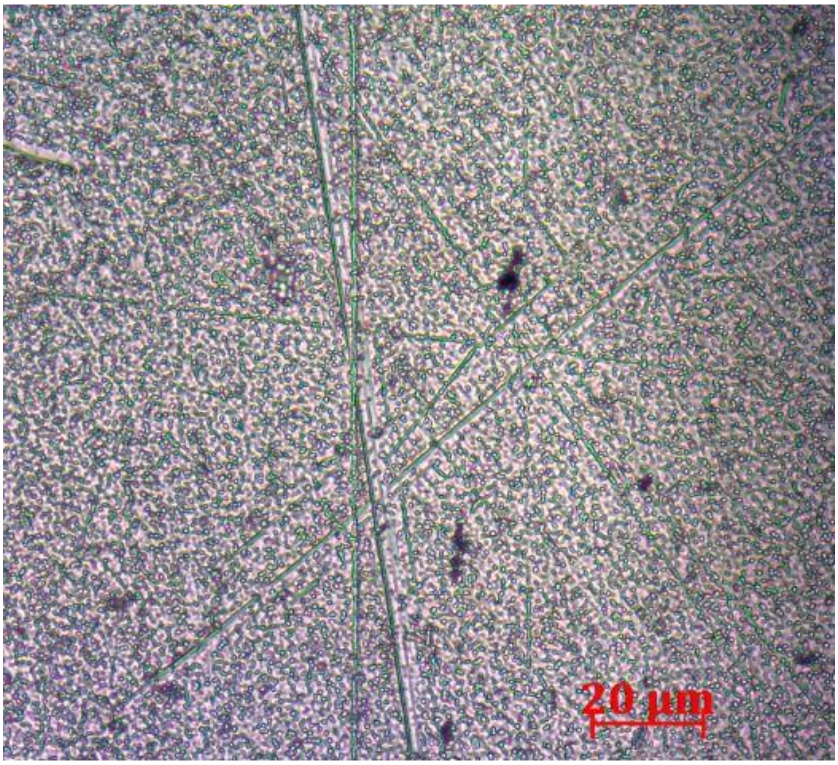



Figure 4.1 Microstructure at 50x magnification

### 4.2.1 Discussion

Figure 4.1 shows an optical micrograph of Al-10% Si alloy. Here, light areas are Al – Si eutectic, the dark dots are pro-eutectic aluminium and the dark patches are PSPs (primary Silicon particles).

## 4.3 Wear Test

The wear tests of Al-Si alloys were carried out with varying applied load of 30N and 80N and varying sliding distance of 2000m, 5000m and 6000m for each value of applied load. The Revolution per minute was kept constant at 480 RPM and Track diameter was held constant at 90mm. Following curves were plotted.

i. Time vs. weight

ii. Time Vs. weight loss

iii. Time Vs Friction

The results from the above tests are noted and corresponding curves are drawn as shown in the next pages.

**Figure 4.2: A typical weared surface**

### 4.3.1Microstructure of worn surface, Frictional Force and Wear Rate

The alloy samples from the wear test with load 30 N and 80 N, sliding speed 480 rpm and sliding distance 2000 m, 5000m and 6000m are taken and their worn surfaces are observed with stereo microscope.Following images show the wear rate, micrographs of orn surfaces taken at low and high magnifications respectively and the friction vs time plot generated by computer.

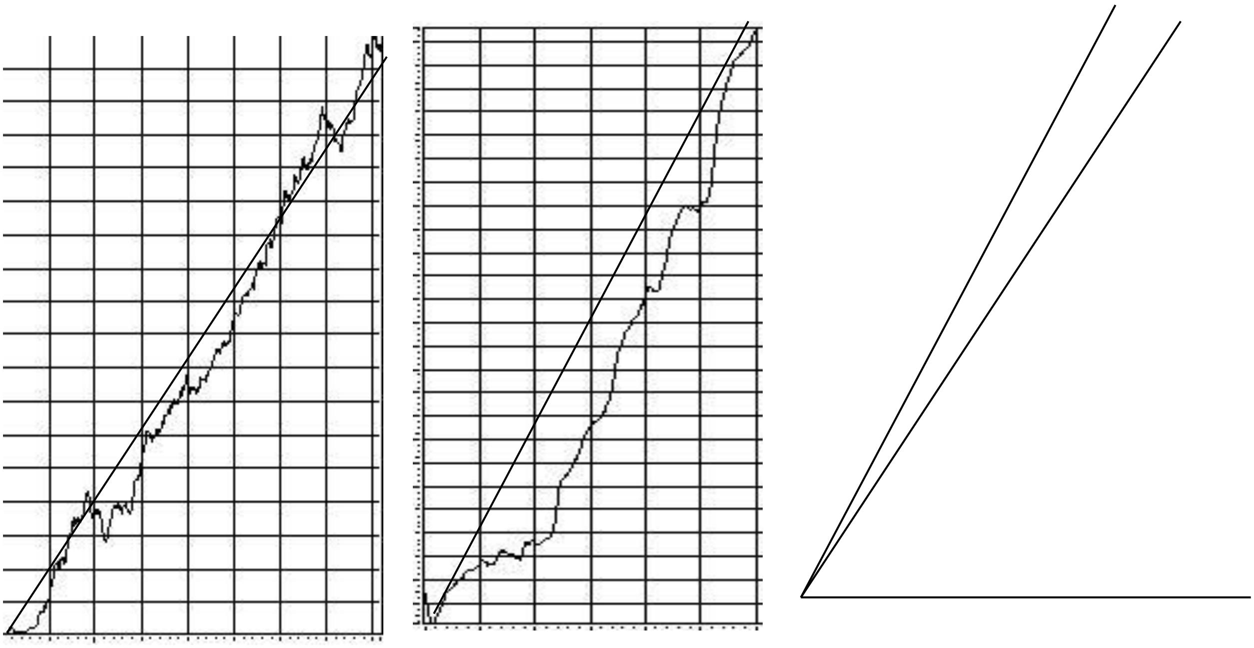
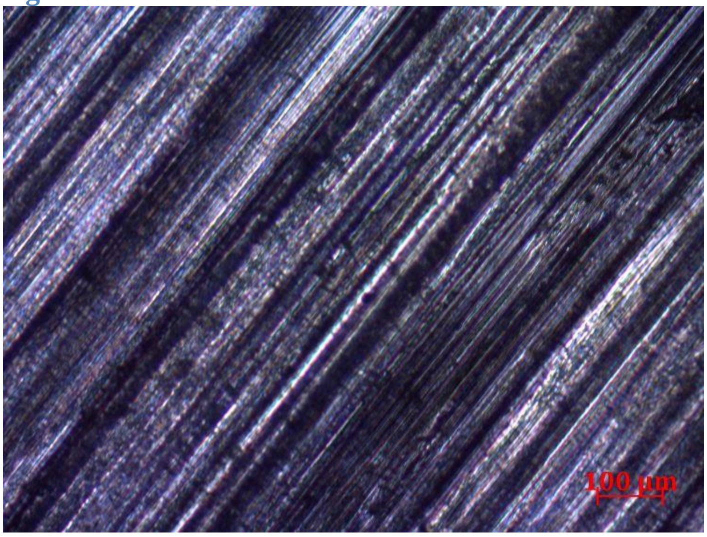
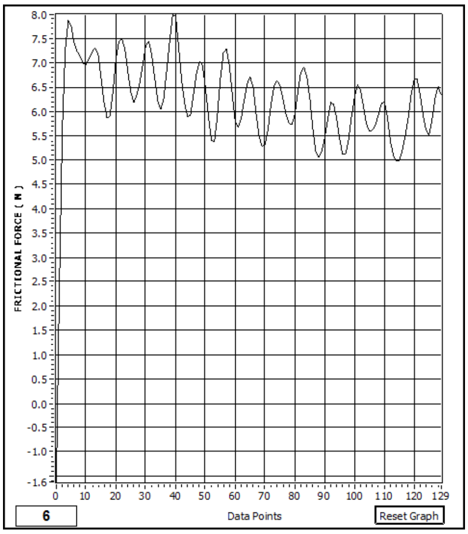


**Figure 4.3: The figure shows the wear rate of the alloys.**

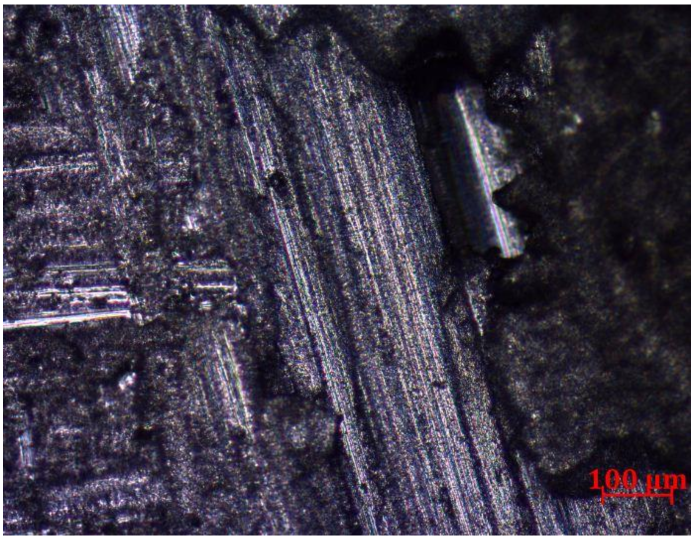
The first figure shows the wear rate when applied load was 30N at sliding distance of 5000m where as the second figure the wear rate when the applied load was 80N at sliding distance of 5000m. The third figure compares the average slope of the of the plots. As evident from the third figure, the average slope for 80N wear rate is greater than the average slope for 30N wear rate. Therefore it is safe to assume that the wear rate increases as the applied load increases.

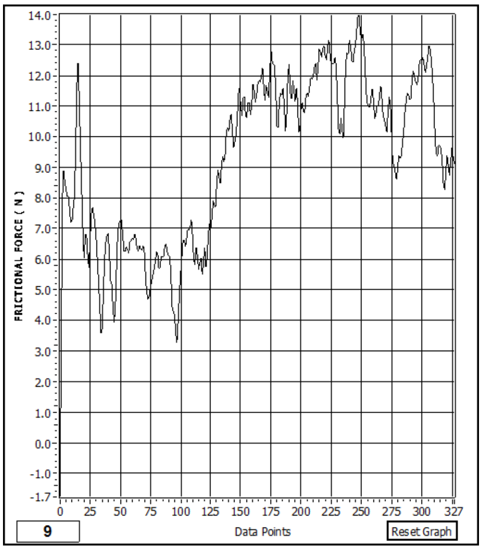
**Parameters:**
**Load: 30 N**
**Track Diamtere: 90mm**
**Sliding Distance: 2000m**
**Magnification: 10x**
**Figure: 4.4 and 4.5**



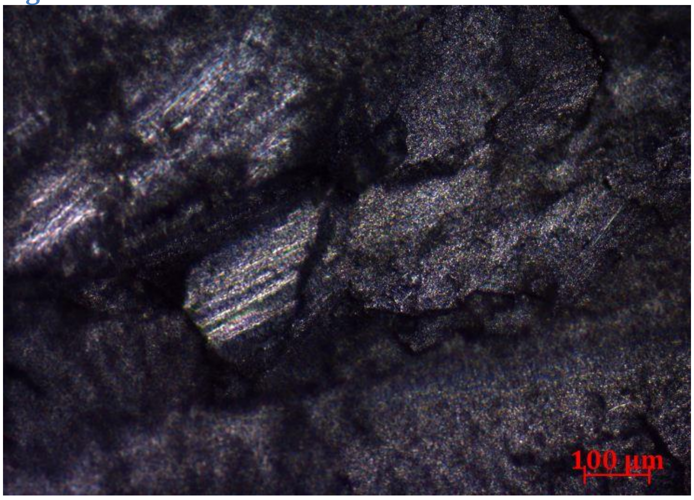



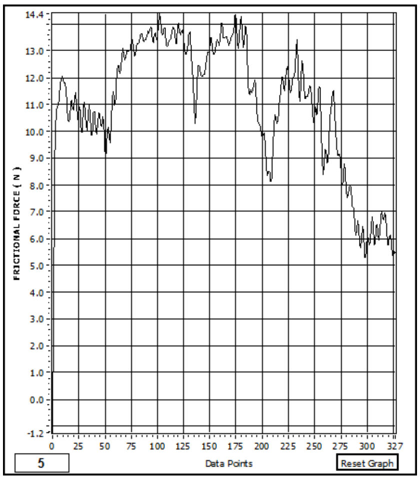

**Parameters:**
**Load: 30 N**
**Track Diamtere: 90mm**
**Sliding Distance: 5000m**
**Magnification: 10x**
**Figure: 4.6 and 4.7**



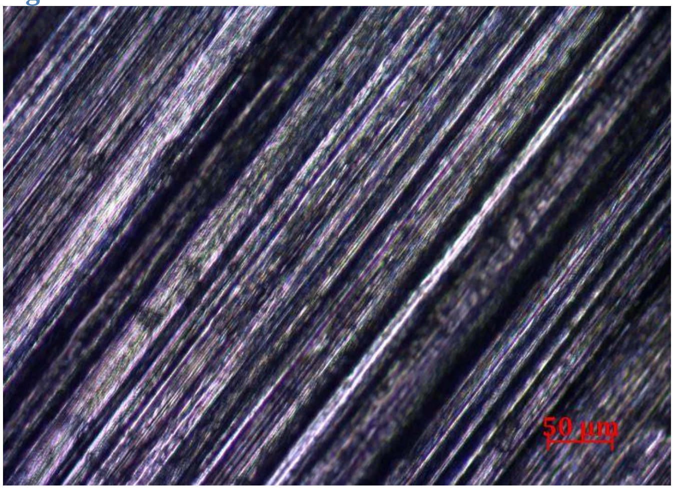



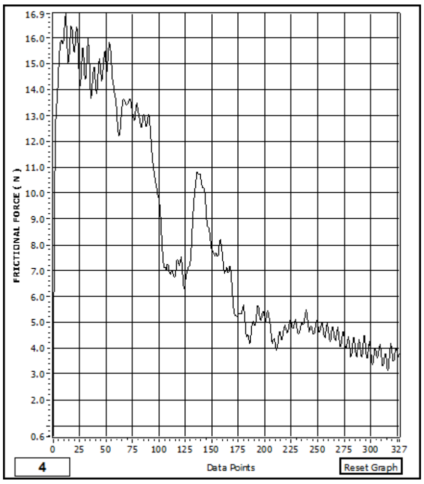
**Parameters:**
**Load: 30 N**
**Track Diamtere: 90mm**
**Sliding Distance: 5000m**
**Magnification: 10x**
**Figure: 4.8 and 4.9**



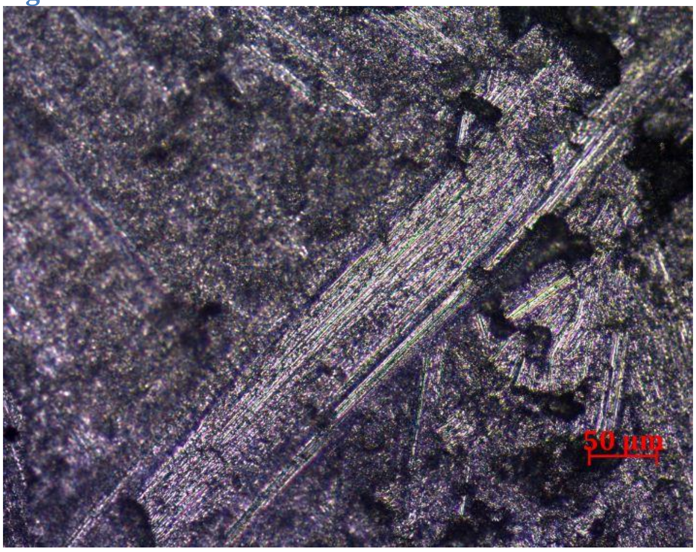



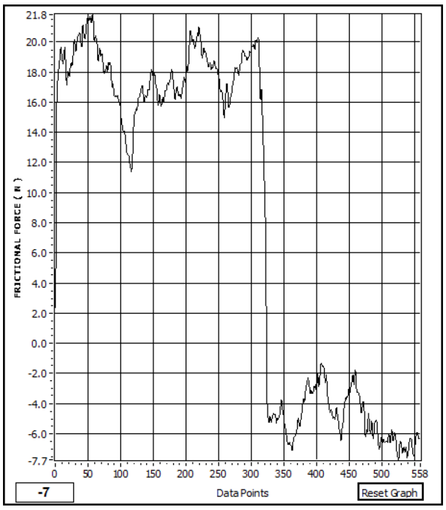

**Parameters:**
**Load: 80 N**
**Track Diamtere: 90mm**
**Sliding Distance: 2000m**
**Magnification: 20x**
**Figure: 4.10 and 4.11**



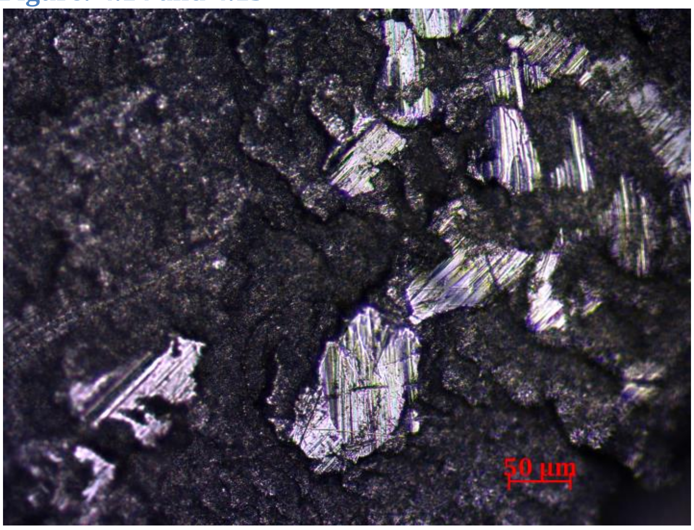



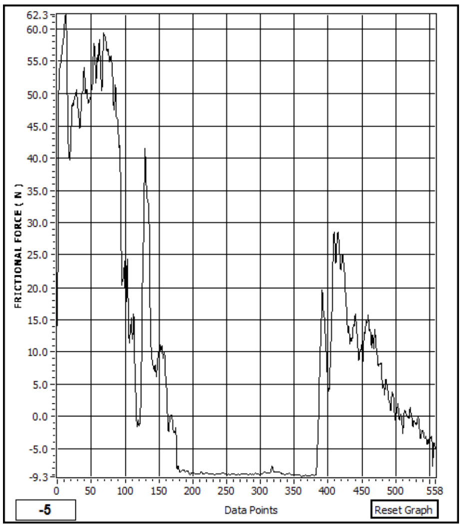
**Parameters:**
**Load: 80 N**
**Track Diamtere: 90mm**
**Sliding Distance: 5000m**
**Magnification: 20x**
**Figure: 4.12 and 4.13**




**Parameters:**
**Load: 80 N**
**Track Diamtere: 90mm**
**Sliding Distance: 5000m**
**Magnification: 20x**
**Figure: 4.14 and 4.15**



The following table and plots show the wear characteristics of the alloys.

**Table 4.1: Weight, weight loss and Time data for 30N and 80N for 2000m sliding distance.**

| Time | Distance | Weight (in gms) (30N) | Weight loss(g) (30N) | | Time | Distance | Weight (in gms) (80N) | Weight loss(g) (80N) |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 4.84 | 0 | | 0 | 0 | 4.7712 | 0 |
| 2 | 271.296 | 4.8344 | 0.0056 | | 2 | 271.296 | 4.7509 | 0.0203 |
| 4 | 542.592 | 4.8301 | 0.0099 | | 4 | 542.592 | 4.7399 | 0.0313 |
| 6 | 813.888 | 4.8254 | 0.0146 | | 6 | 813.888 | 4.7342 | 0.037 |
| 8 | 1085.184 | 4.8234 | 0.0166 | | 8 | 1085.184 | 4.7289 | 0.0423 |
| 10 | 1356.48 | 4.8227 | 0.0173 | | 10 | 1356.48 | 4.728 | 0.0432 |
| 12 | 1627.776 | 4.8198 | 0.0202 | | 12 | 1627.776 | 4.7237 | 0.0475 |
| 14.7 | 1994.026 | 4.8161 | 0.0239 | | 14.7 | 1994.026 | 4.7199 | 0.0513 |

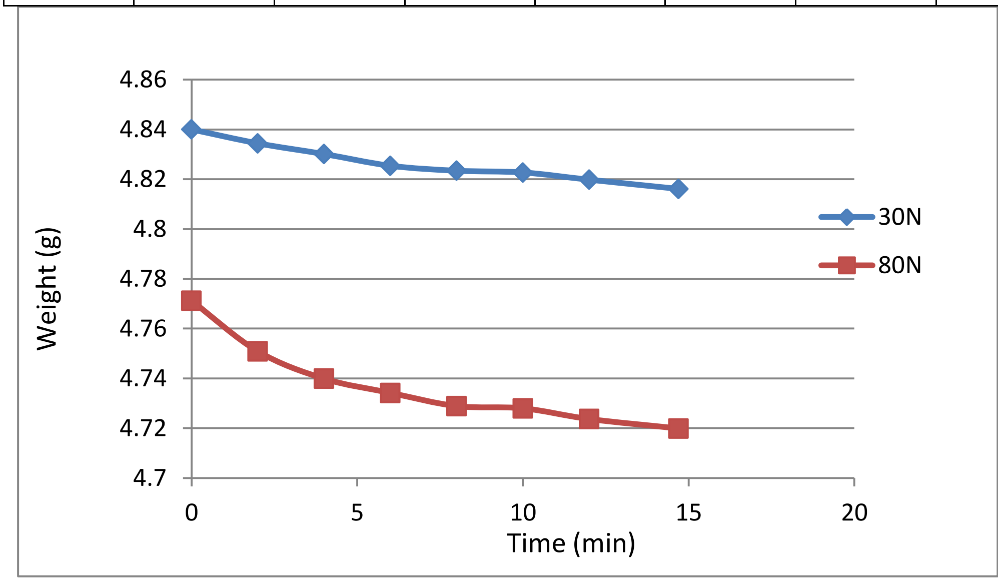



**Figure 4.16: Plot of Weight Vs Time for 2000m**

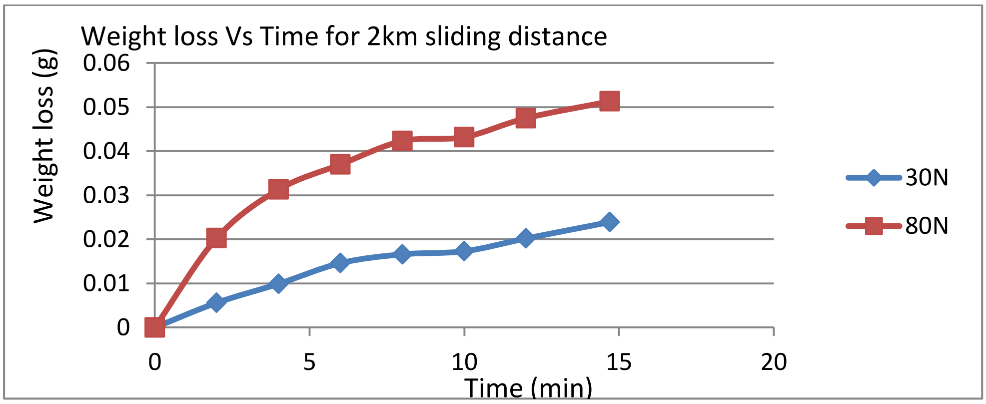



**Figure 4.17: Plot of weight loss Vs Time for 2000m**

Table 4.2 : Weight, weight loss and Time data for 30N and 80N for 5000m sliding distance.

| Time | Distance | Weight (in gms) (30N) | Weight loss(g) (30N) | | Time | Distance | Weight (in gms) (80N) | Weight loss(g) (80N) |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 4.8 | 0 | | 0 | 0 | 4.6982 | 0 |
| 5 | 678.24 | 4.7812 | 0.0188 | | 5 | 678.24 | 4.6612 | 0.037 |
| 10 | 1356.48 | 4.7803 | 0.0197 | | 10 | 1356.48 | 4.6489 | 0.0493 |
| 15 | 2034.72 | 4.7742 | 0.0258 | | 15 | 2034.72 | 4.6395 | 0.0587 |
| 20 | 2712.96 | 4.7685 | 0.0315 | | 20 | 2712.96 | 4.6278 | 0.0704 |
| 25 | 3391.2 | 4.7664 | 0.0336 | | 25 | 3391.2 | 4.6198 | 0.0784 |
| 30 | 4069.44 | 4.7633 | 0.0367 | | 30 | 4069.44 | 4.6087 | 0.0895 |
| 36.85 | 4998.629 | 4.7567 | 0.0433 | | 36.85 | 4998.629 | 4.6043 | 0.0939 |

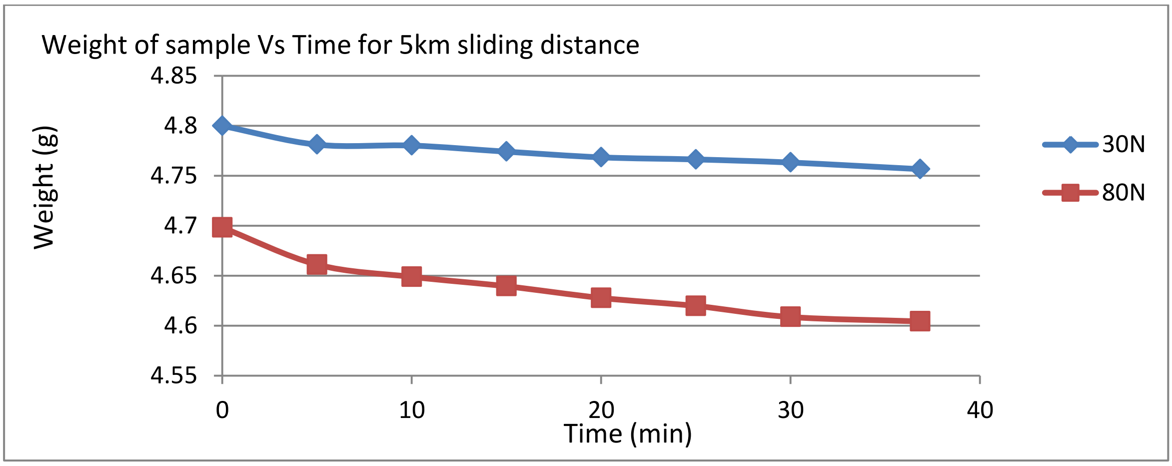



Figure 18: Plot of Weight Vs Time for 5000m

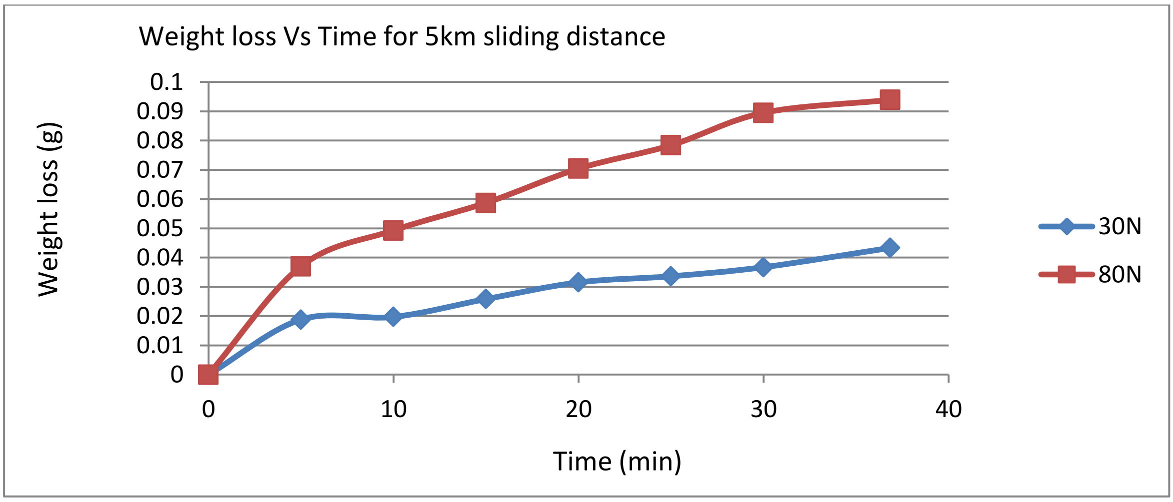



Figure 19: Plot of weight loss Vs Time for 5000m

**Table 4.3: Weight, weight loss and Time data for 30N and 80N for 8000m sliding distance.**

| Time | Distance | Weight (in gms) (30N) | Weight loss(g) (30N) | | time | distance | Weight (in gms) (80N) | Weight loss(g) (80N) |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 4.7043 | 0 | | 0 | 0 | 4.0283 | 0 |
| 8.5 | 1153.008 | 4.6735 | 0.0308 | | 8.5 | 1153.008 | 3.8247 | 0.2036 |
| 17 | 2306.016 | 4.535 | 0.1693 | | 17 | 2306.016 | 3.6231 | 0.4052 |
| 25.5 | 3459.024 | 4.4131 | 0.2912 | | 25.5 | 3459.024 | 3.4986 | 0.5297 |
| 34 | 4612.032 | 4.2507 | 0.4536 | | 34 | 4612.032 | 3.2921 | 0.7362 |
| 44.2 | 5995.642 | 4.192 | 0.5123 | | 44.2 | 5995.642 | 3.2654 | 0.7629 |
| | | | | | | | | |

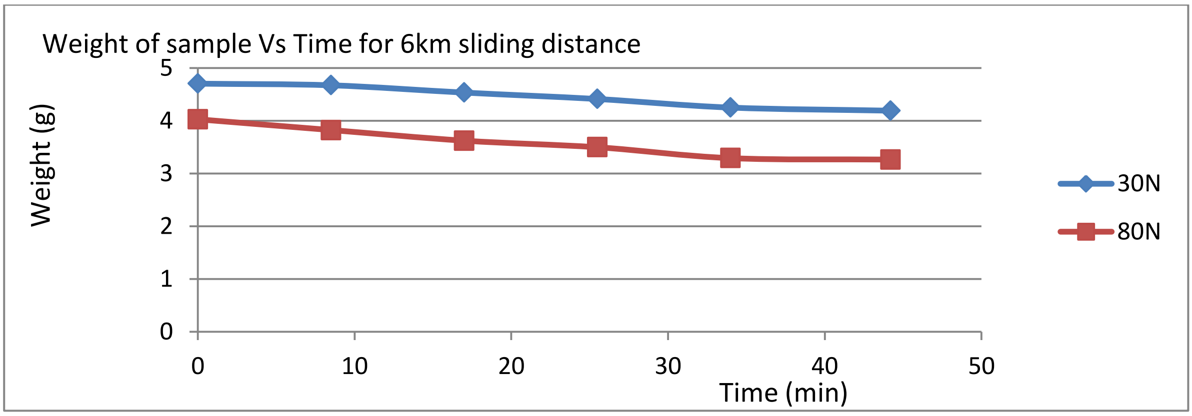



**Figure 20: Plot of Weight Vs Time for 6000m**

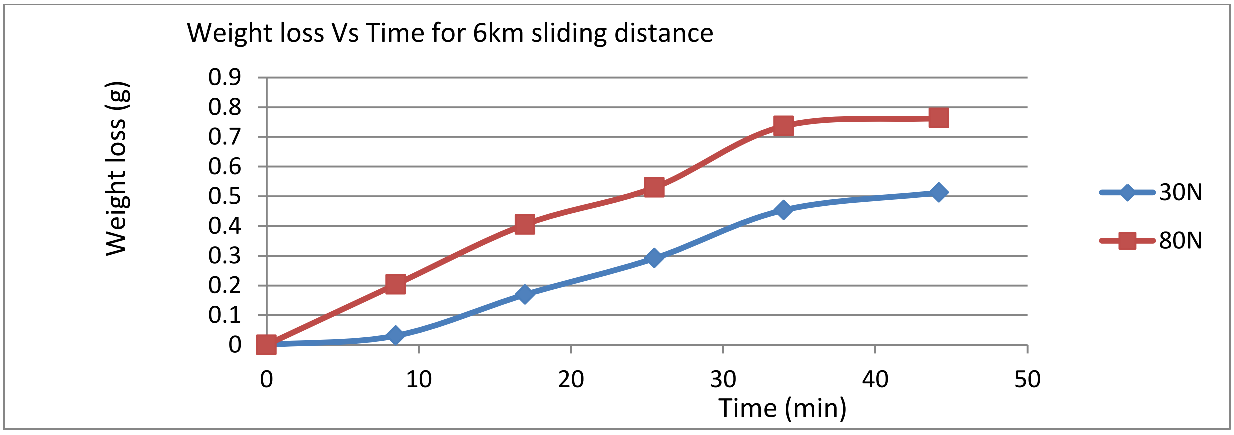



**Figure 21: Plot of weight loss Vs Time for 5000m**

Weight loss Vs. Distance for different loads

| Dist | 30N | 80N |
|---|---|---|
| 2000 | 0.0239 | 0.0513 |
| 5000 | 0.0433 | 0.0939 |
| 6000 | 0.5123 | 0.7629 |

**Table 4.4: Distance vs Weight loss for different loads**

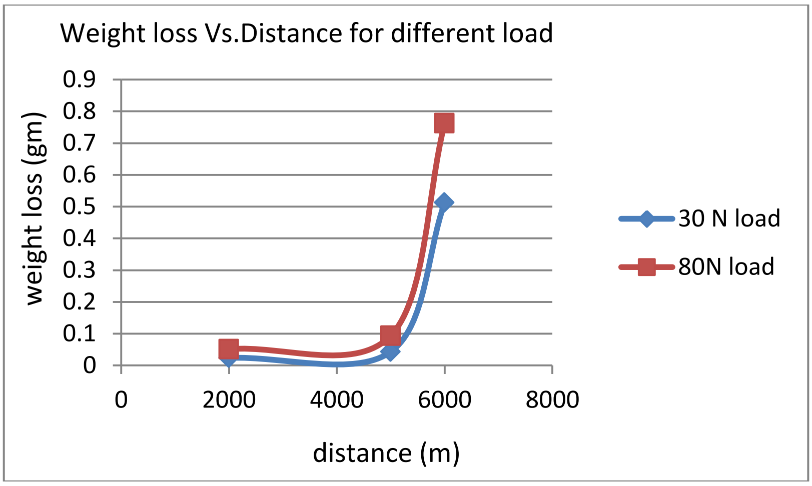



**Figure 22: Plot of distance Vs Weight loss for different loads.**

### 4.3.2 Discussion

- The increase in slope of "Wear Vs Time" plot from the 30N load test to 80N load test, signifies the fact that wear rate increases with increase in applied load.
- The microstructure for 30 N load and 2000m sliding distance showed uniformity of orientation of cracks where as the uniformity gradually loses when the applied load or sliding distance increased. Also, as the load/sliding distance increased, the focused/defocused area increased. Therefore, it safe to say that increase in load or sliding distance increases the wear.
- The weight loss rate is initially high, but this rate gradually decreases as time increases. This is due to the change in mechanism of wear.
- Also, it is evident from the "Weight loss Vs Time" plots that rate of weight loss is greater for greater load. Thus, we may conclude that wear rate increase with increase in load.
- The weight loss vs distance curve showed a sudden increase in slope of the curve. This may be due to the extreme vibration that was observed in the ducom machine, excessive loss of fractured sample flanges while unloading the sample from the sample holder or other random experimental faults.

## 4.4 Profilometer

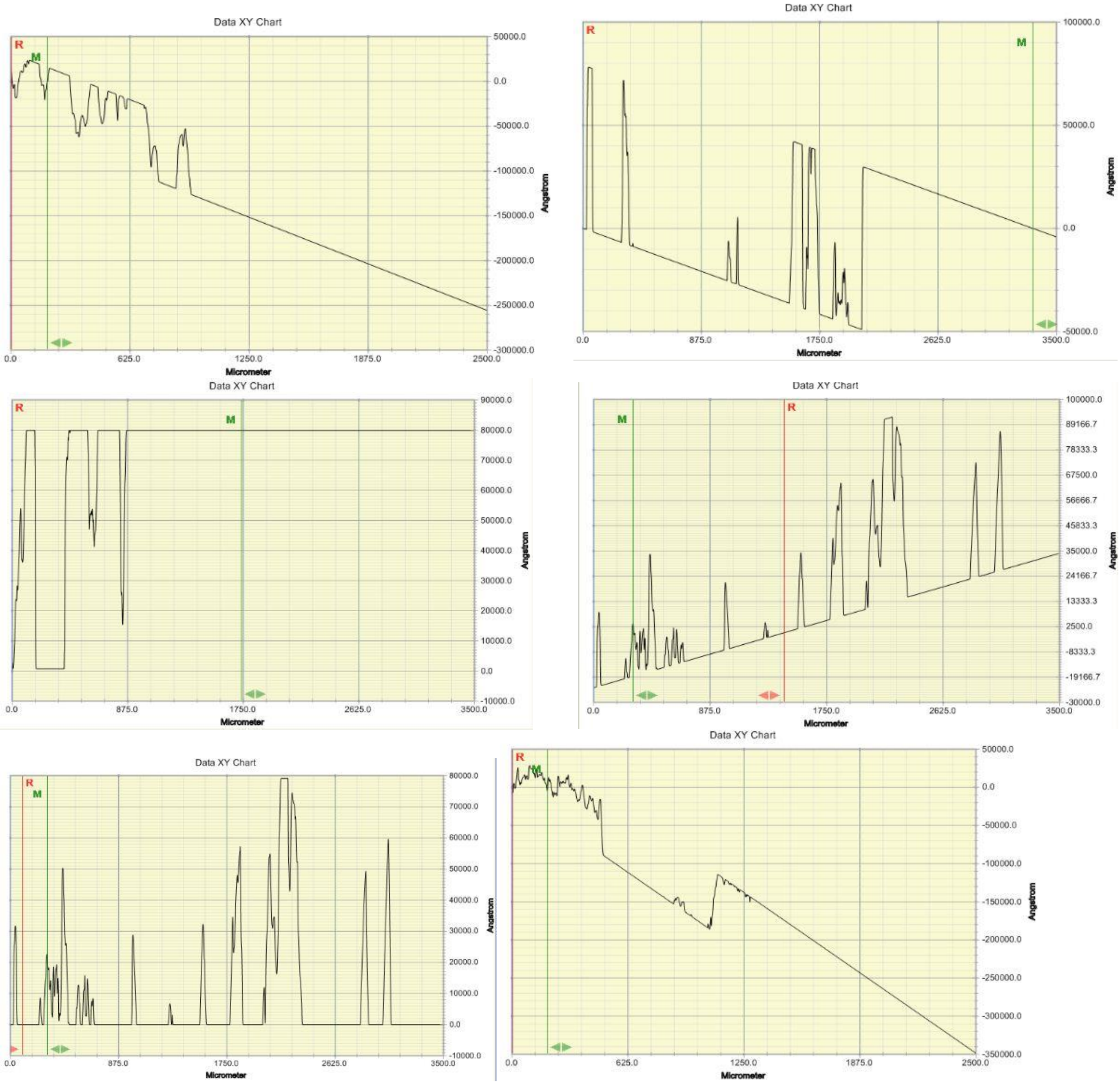



Figure 23: Profilometer curves from left to right and top to bottom are as follows:

1. Sliding distance: 2000m and Load: 30N
2. Sliding distance: 5000m and Load: 30N
3. Sliding distance: 6000m and Load: 30N
4. Sliding distance: 2000m and Load: 80N
5. Sliding distance: 5000m and Load: 80N
6. Sliding distance: 6000m and Load: 80N

### 4.4.1 Discussion

By a careful observation of the Profilometer curves, it was evident that the surface roughness increased as the load and distance increased.

# CHAPTER – 5

# CONCLUSION

The conclusions drawn from the conducted investigations are as follows:

1. The prepared aluminium-silicon alloys have homogenous distribution of silicon throughout the cast. The presence of proeutectic silicon can be seen through the microstructure.

2. The increase in slope of "Wear Vs Time" plot from the 30N load test to 80N load test, signifies the fact that wear rate increases with increase in applied load.
3. The microstructure for 30 N load and 2000m sliding distance showed uniformity of orientation of cracks where as the uniformity gradually loses when the applied load or sliding distance increased. Also, as the load/sliding distance increased, the focused/defocused area increased. Therefore, it safe to say that increase in load or sliding distance increases the wear.
4. The weight loss rate is initially high, but this rate gradually decreases as time increases. This is due to the change in mechanism of wear.
5. Also, it is evident from the "Weight loss Vs Time" plots that rate of weight loss is greater for greater load. Thus, we may conclude that wear rate increase with increase in load.
6. The weight loss vs distance curve showed a sudden increase in slope of the curve. This may be due to the extreme vibration that was observed in the ducom machine, excessive loss of fractured sample flanges while unloading the sample from the sample holder or other random experimental faults.

7. By a careful observation of the Profilometer curves, it was evident that the surface roughness increased as the load and distance increased.

8. Hardness increases as Aging Time increases due to Precipitation of GP Zones or metastable phases.

9. When aging temperature is high, there could be dissolution of GP zones or metastable phases and thus reduction in hardness. In such a case hardness peak would be obtained.

10. Aging temperature improves wear properties empirically verifying that wear improves concurrently with improve in hardness. So, given an aging temperature of around 200 C and time of approximately 8 hrs, best wear properties would be obtained at 200 C aged for 6 hours.

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