STUDY AND ANALYSIS OF ABRASIVE WEAR CHARACTERISTICS OF ALLOY STEEL (AISI 52100) AND ALUMINIUM UNDER LUBRICATION BY USING PIN-ON-DISC APPARATUS

A Thesis

Submitted

In Partial Fulfillment of the Requirements

For the Degree of

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In

Mechanical Engineering

With Specialization

In

"Production and Industrial Engineering"

Submitted by

Parvez Ahmad

Enrollment No. 1900101398

Department of Mechanical Engineering

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September, 2021

CERTIFICATE

This is to certify that **Mr. Parvez Ahmad** (Enroll. No. 1900101398) has carried out the research work presented in the thesis titled **“Study and Analysis of abrasive wear characteristics of Alloy Steel (AISI 52100) and Aluminium under lubrication by using Pin-on-disc apparatus”** submitted for partial fulfillment for the award of the **Degree of Master of Technology in Production and Industrial Engineering** from **Integral University, Lucknow** under my supervision.

It is also certified that:

(i) This thesis embodies the original work of the candidate and has not been earlier submitted elsewhere for the award of any degree/diploma/certificate.

(ii) The candidate has worked under my supervision for the prescribed period.

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Signature of Supervisor
Dr. Mohd. Shadab Khan
Associate Professor
Department of Mechanical Engineering
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Date: 11/09/2021
Place: Lucknow

CERTIFICATE

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Signature of Co-Supervisor

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Place: Lucknow

DECLARATION

I hereby declare that the thesis titled "**Study and Analysis of abrasive wear characteristics of Alloy Steel (AISI 52100) and Aluminium under lubrication by using Pin-on-disc apparatus**" is an authentic record of the research work carried out by me under the supervision & co-supervisor Dr. Mohd. Shadab Khan, Associate Professor & Er. Abdul Ahed Khan, Assistant Professor, Department of Mechanical Engineering, Integral University, Lucknow. No part of this thesis has been presented elsewhere for any other degree or diploma earlier.

I declare that I have faithfully acknowledged and referred to the works of other researchers wherever their published works have been cited in the thesis. I further certify that I have not willfully taken other's work, para, text, data, results, tables, figures etc. reported in the journals, books, magazines, reports, dissertations, theses, etc., or available at web-sites without their permission, and have not included those in this M.Tech. thesis citing as my own work.

Date: 11/09/2021

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Parvez Ahmad

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LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS

ABSTRACT

Aluminium alloys have extensive application in industries. The range of physical properties that can be imparted to them is remarkable. Aluminium alloys are extensively used in industrial applications due to better tribological properties. In the present work, an attempt has been made to study the tribological properties of hardened Steel (AISI52100) and Aluminium at three different speed of grinding wheel disc (250 rpm,500 rpm, and 750 rpm) and applied loading condition (5N,10N and 15N). Wear tests were conducted using a pin-on-disc type wear testing machine. The operational parameters that were varied were normal load, sliding speed, and lubrication.

The results of the study revealed that as the speed of grinding wheel disc and load increases the wear rate of alloy steel progresses simultaneously. The maximum wear occurs at 750 rpm speed of grinding wheel for 15N load whereas minimum wear occurs at 250rpm speed of grinding wheel for 5N load.

CHAPTER 1

INTRODUCTION

1.1GENERAL

AISI 52100 is a high quality bearing steel alloy. It is a solution treated hardened low alloy steel, which contains high carbon, chromium, and manganese. The hardness is in the range of 55 to 60 HRC. It shows light tempered marten site, less amount of retained austenite, and primary carbides in the microstructure after hardening. Hence, it exhibits improved mechanical properties such as tensile strength, yield strength, high bulk, and shear modulus properties. AISI 52100 steel poses excellent wear resistance against dynamic loading; therefore, it is extensively used in valve bodies, pumps and fittings, transmission shafts, locomotives, machine tools, tractors, and mining machinery components [1].

However, many industrial applications such as bearing, gauges, and dead centers require a hardened AISI 52100 to improve their wear resistance. The conventional manufacturing processes of these components are the preparation of blanks using forging or casting, annealing to relieve stresses, rough machining, finish machining, hardening, andfinish grinding. These processes require a long processing time resulting in a reduction of productivity and degraded product quality. Thus, hard turning with a potential benefit such as shorter setup time, high flexibility, and ability to handle complex geometry is an alternative machining process that replaces the finish machining and finish grinding step for machining of AISI 52100 steel [2].

However, hard turning has different challenges in machining, which are high cutting forces, rapid tool wear, and high cutting zone temperature, which leads to unacceptable surface integrity .The surface integrity of the machined components, plays a vital role in its functional performance and service life. It is measured in terms of white and dark layers, microstructure alteration, surface roughness, residual stresses, and micro hardness [3].

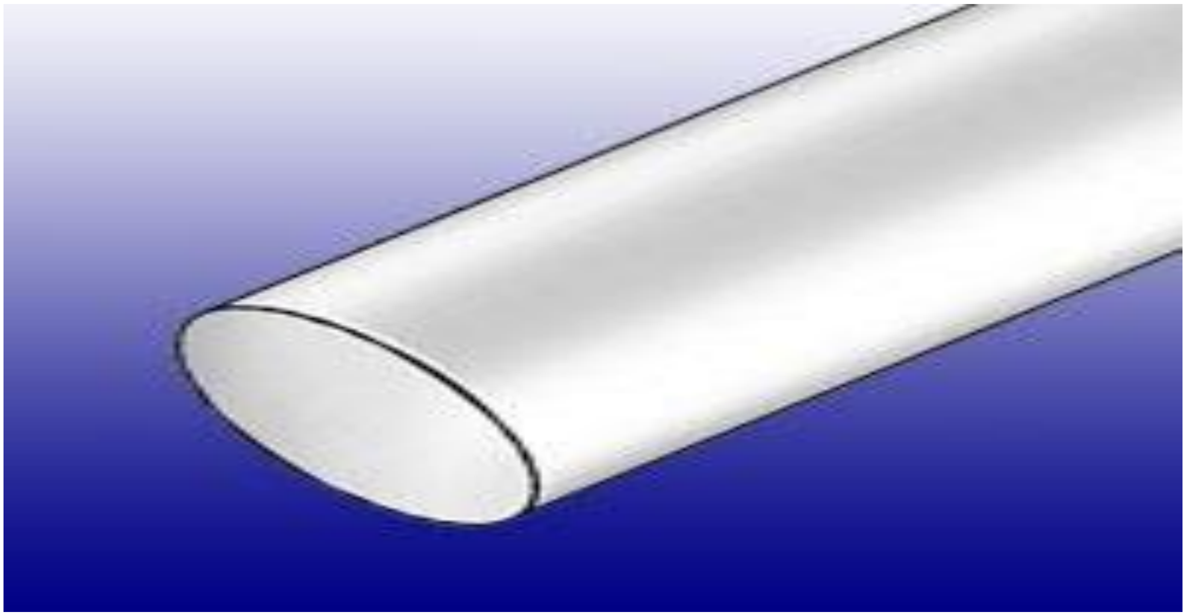

Fig.1.1 AISI 52100 Alloy Steel.

1.2: Wear

When two surfaces comes in contact with each other and there is a relative motion between these two surfaces. This leads to loss of material from the surface. This loss of material is called as wear. Wear lead to the loss of mechanical properties of material. It occurs due to the plastic deformation of the material.

Today there are many methods to determine the wear of a material under the specific condition. ASTM international produces a standard wear testing for specific application.

When the loss of dimension of an engineering component exceeds the limit of tolerance, then the life of that engineering component ends. Wear is an ageing process and as the age increases it leads to the failure of material. Like wear, other ageing processes are fatigue stress which depends on the fatigue concentration and repeated load.

Wear is one of the slow processes. Due to wear, component losses its enormous properties and leads to failure.

There are three stages of wear in any components:-

- Primary stage is run in period, in which the material contact is necessary. In this stage, the wear may be high and low.

- Mid age process, in which the steady rate of ageing, occurs. This is the period for mostof operational component life.
- Old age period, in which the components are failing very high rate.

1.3: Types of wear

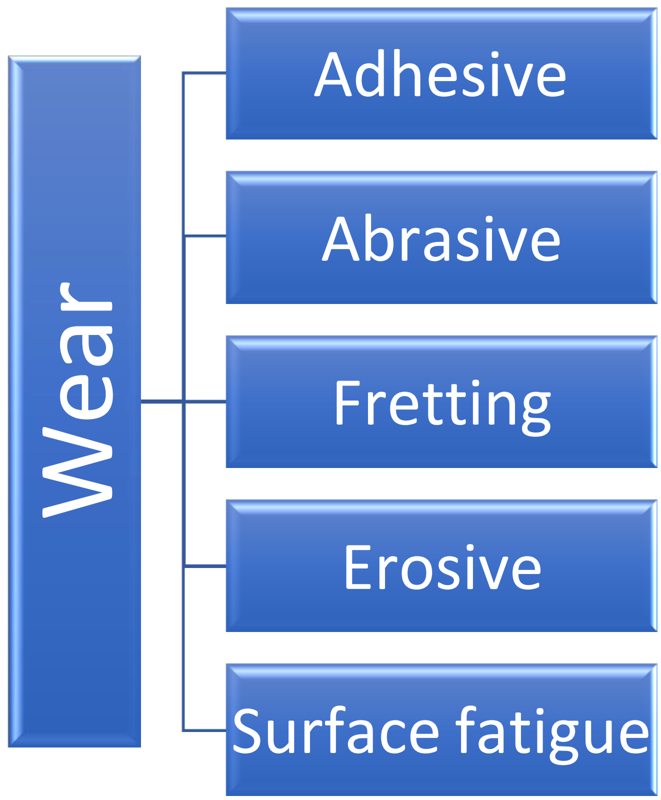

Fig.1.2. Types of Wear

1.3.1: Adhesive Wear: It occurs due to the surface friction between two contacting surfaces and are refers to as unwanted displacement and attachment of wear particle. Adhesive wear occurs due to the relative motion of the contacting surfaces and cohesive forces between the materials in contacts. When one body slides over other than adhesive wear occurs. It leads to the surface roughness and lumps.

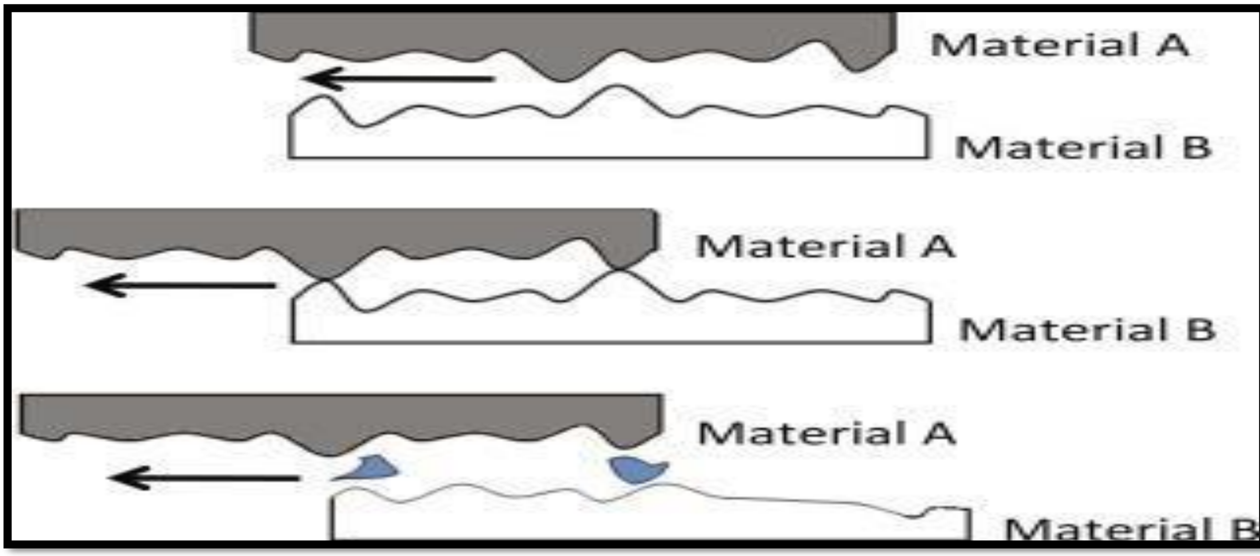

Fig.1.3. Adhesive wears

1.3.2: Abrasive wear

It occurs when a harder surface slides over the softer surfaces. It depends on the type of contact & contact environments. It further classified as two bodies and three body abrasion wear. Two body occurs when a hard surface grit remove the material from other surface that is opposite to it. In three bodies, abrasion wear the particle in between two surfaces is free to move and roll. Mechanism for the identification of abrasion wear is plowing, cuttingand fragmentation. Abrasion wear can be measured by loss of mass by Taber Abrasion test.

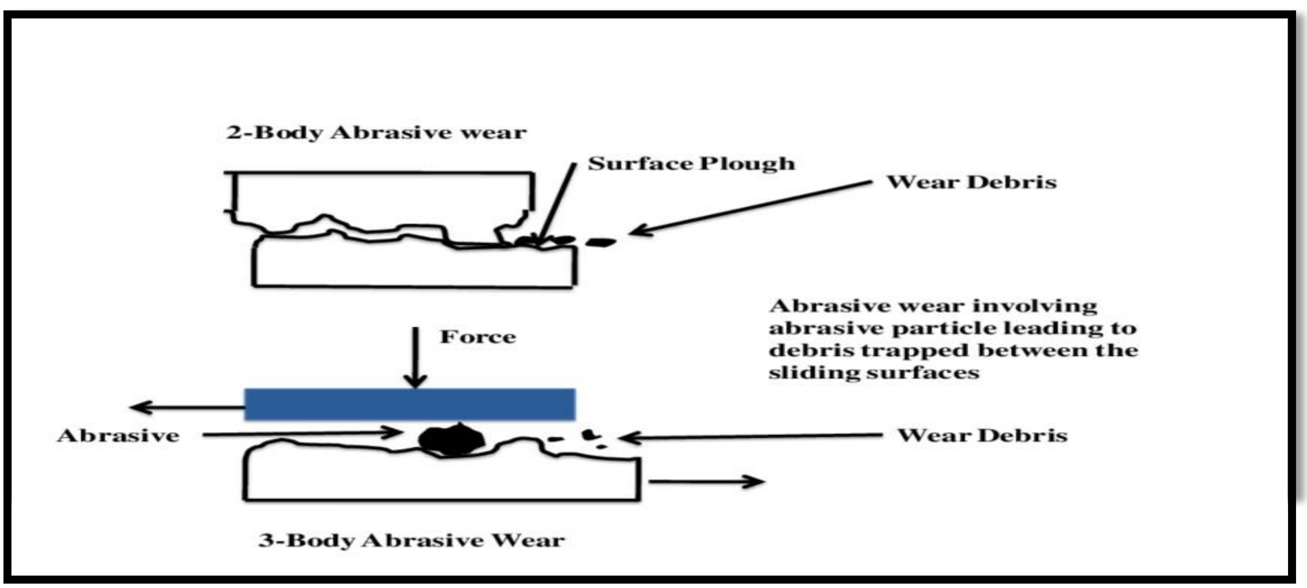

Fig.1.4. Abrasive wear

1.3.3: Fretting Wear: fretting means repeated cyclic rubbing between two surfaces and this leads to the removal of material from one surface or both surfaces. Bearing is an example of this type of wear. Fretting leads to the fretting corrosion in present of water.

1.3.4: Erosive Wear: It exists for short period of time. Erosive wear occurs when particle or liquid forces to impact on the material with a force. Due to impact of the particle, the wear occurs. It is widely seen in industry. The rate of erosive wear depends on particle hardness, distance between nozzle and material surface, angle of impact and other factors .When Angle of impact reaches 300 the highest wear occurs in ductile material. While that for brittle material, the angle of impact should be normal to the surface for maximum wear to occur.

- **Erosive wear is further classified into two categories:**
- Liquid-droplet erosion
- Solid-particle erosion

Liquid-droplet erosion: Damage of target particle under the continuous impact of liquid droplet is defined as Liquid-droplet erosion. The problem of Liquid-droplet is uncounted in high-speed aircrafts, missiles and steam turbines. The liquid- solid droplet velocity is dependent on impact velocity and the radius of droplet. The response of brittle materials under liquid impact leads to generation of cracks surrounding the area. The cracks generated in the form of discontinuous annular rings which results in material removal from the surface. The behavior of ductile metals is somewhat different from the response given by brittle materials. In ductile material due to impingement of liquid droplet there is suppression of metal at the Centre while the outer edge gets raised.

Solid-particle erosion: Loss of material under the impact of particles on the solid surface is called as solid-particle erosion. The carrier medium for solid particle can be either gas or liquid. A pipeline dealing with slurry transportation regularly faces the problem of solid-particle erosion. AR chard law predicted that erosion rate is inversely proportional to the hardness of the material but experimental result proved that it's inversely proportional to square of hardness value.

1.3.5: Fatigue Wear: A cycling loading causes fatigue wear of a material during friction. Fatigue occurs if the applied load is higher than the fatigue strength of the material. Fatigue cracks start at the material surface and spread to the subsurface regions. The cracks may connect to each other resulting in separation and delamination of the material pieces.

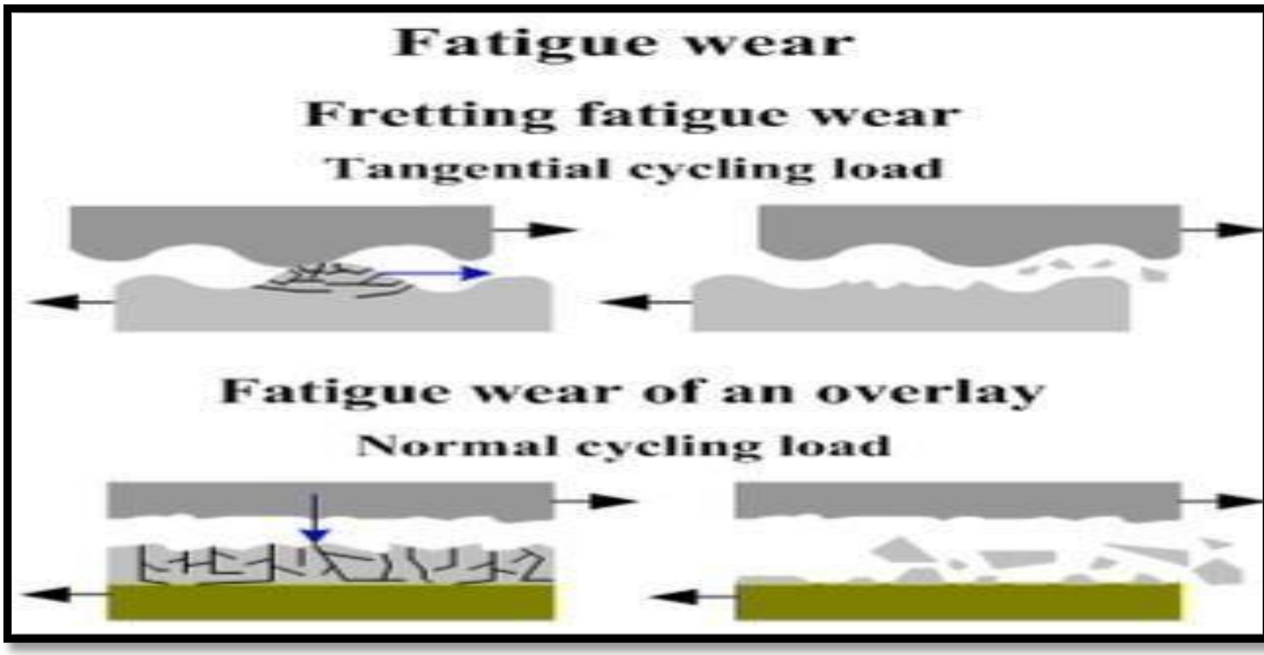

Fig.1.5.Fatigue Wear

1.4. Wear Testing Machines or Tribometers:

Wear testing machines are used to assess the erosion or displacement of solid surface underthe impact of another surface or particle. Wear testing helps to determine the workability ofthe sample or specimen, which is going to be used in industries. Testing can be performed under various environmental conditions to simulate actual working scenarios.

1.4.1. Miller testing apparatus (ASTM G-75):

Miller testing apparatus is based on the procedure given under ASTM G-75 standard. The Miller number is used to rank the abrasiveness of slurries in terms of wear of standard reference manual. Slurry Abrasive of material (SAR number) is an index to determine the abrasive response of different material under slurry conditions.

1.4.2. Jet Impingement Tester (ASTM G73-82):

In this experimental procedure, the solid specimen is continuously eroded by the impact of liquid jet. This test is performed for the evaluations of corrosion behavior of specimen. In this method, water is sprayed through the nozzle on the solid specimen. It comprises of a pump and an ejector to issue a jet through a nozzle. Jet impingement tester simulates the wear for direct impact of solid particles in equipment such as pumps, bends, tee junctions, elbows, contractions etc. This method is not applicable for predicting erosion wear or particle impact in bouncy flow.

1.4.3. Pin-on disk Apparatus (ASTM G99):

This method measures the wear rate of materials using pin-on-disk apparatus. This method also helps in determining the coefficient of friction. During this tribological test, the pin rotates against a stationary disk under constant load. The amount of wear is determined by measuring appropriate linear dimensions of both specimens before and after the test, or by weighting both specimens before and after the test.

1.5 Advantages of Wear test and Disadvantage of Wear test

1.5.1Advantages of Wear test:

Wear test after run-in, surface pressure remains constant. Easy to determine wear volume and wear rate. The model closely simulates a linear friction bearing.

1.5.2. Disadvantage of Wear test:

Difficult to align pin. If the pin does not stand perfectly vertical on the plate, edge contact results. A very long run-in time is therefore necessary. The front edge of the pin can skim off lubricant. This makes a defined lubrication state impossible.

CHAPTER 2

LITERATURE REVIEW

A. Tucci, L. Esposito et. al. in (1994) they studied the zirconium di-oxide and alumina. They studied sliding against the pin-on-disc tribometer. They found that the at all velocity the coefficient of friction is very low. They studied the surface by SEM and found out that the wear is due to abrasion and plastic deformation.

Bhushan, B. in (2002) they studied due to their light weight, high corrosion resistance and good heat conductivity, aluminium alloys are used in many industries today. They are suitable for manufacturing many automotive components such as clutch housings. These alloys can be fabricated by powder metallurgy and casting methods, in which porosity is a common feature. The presence of pores is responsible for reducing their strength, ductility and wear resistance. The present study aims to establish an understanding of the tribological behavior of high pressure die cast Al A380M and powder metallurgy synthesized Al 6061. In this study, dry sliding wear behavior of Al A380M and Al 6061 alloys was investigated under low loads (1.5 N – 5 N) against AISI 52100 bearing steel ball using a reciprocating ball-on-flat configuration and frequency of 10 Hz. Wear mechanisms were studied through microscopic examination of the wear tracks. This study revealed that due to combined effect of real area of contact and subsurface cracking, wear rate increased with increasing porosity content. The difference in friction and wear behavior between received Al A380M and Al 6061 is attributed to their hardness differences.

Andrew W. Batchelor, et. al in (2006) the empirical method are employed for surface coating so there is not any clear idea about which of the surface treatment is best suited for the specific application. Wear resistance substances are very expensive in bulk but forsmall film they provide good economic and minimizing the wear problem. Lubrication position method is should be critically efficient because even powerful lubricant can scrapeoff if the deposition method is incorrect.

Tuti Y. Alias, et. al. in (2011) have studied the wear behaviour of as-cast and heat treated Al-Si eutectic alloys. Wear tests on the alloys were performed on a pin on disk type wear testing apparatus and parameters were size and shape of the pin, load, speed and the material pairs. Increase in the rotational speed of the disk leads to the increase in the mass loss of the ascast and heat treated alloys. The wear rate is higher for as-cast samples. High speed leads to reduction in wear rate. The reduction is pronounced in heat treated samples. This is because during sliding, heat is developed and the material becomes softer and weaker. This heat might not affect the hardness of heat treated alloys due to their inherent characteristics. Increase in the applied load leads to a high wear rate for both as-cast and heat treated alloys. But at higher loads, strain-hardening of the materials in contact increases, resulting in increase in the resistance to abrade or erode. At higher load, real surface area in contact is more which increases the gripping action and due to which wear rate slows down At longer sliding distances, volumetric wear rate and specific wear rate are low. This was attributed to the fact that during sliding, heat develops due to friction which makes some of the adhered materials soften and loosen. As sliding goes on, these loosened particles are thrown away showing higher loss in weight. Heat treated alloys are not much affected due to their inherent characteristics due to heat treatment cycles whereasas cast alloys show higher weight loss.

Amal Ebrahim NASSAR et.al. in (2011) This study was carried out to design and fabricate a cost effective and efficient wear tester (pin on disc) used in the metallurgy research field. Design and calculations were established and the machine was fabricated with well selected materials and components all sourced locally. The performance of the fabricated machine was finally evaluated against a standard wear machine in the Standards Organization using statistical methods and the result showed that the locally fabricated machine is 97% effective.

Ajay Sharma, Narendra Singh et.al. in (2013) have studied the unlubricated sliding of metal parts is important in many mechanical devices covering a wide range of sliding velocities. However, the effect of sliding velocity of the tribological behaviour of unlubricated metal parts has not been widely studied. Similarly, the relationship between microstructures developed at high sliding velocities and tribological behaviour have not been studied in depth. A tribometer is an instrument that measures tribological quantities, such as coefficient of friction, friction force, and wear volume, between two surfaces in contact. Different types of tribometer are four balls, Pin on disc, Block on ring, Bouncing ball and twin disc. The main focus of our research study is pin on disc tribometer, which is an advanced tribometer with precise measuring of friction and wear properties of combination of metals and lubricants under selected conditions of load, speed and temperature. The main element of this tribometer are a pin sliding on the flat face of the disc in a vertical plane with provisions for controlling load, speed and oil temperature and for measuring friction. This is the simplest form of tribometer used to measure wear and friction between two metals. This research relates to the various aspects (coefficient of friction, wear patter, lubrication testing, result graphs) obtained by pin on disc tribometer.

DTL Ramos, et. al. in (2014) have studied, The study deals with the design, manufacture and validation of a pin-on-disc wear test bench. Studies of friction and wear of ceramic sliding have generally used pin-on-disc equipment. This type of equipment has been referred to as one that best represents the wear study and that presents the best reproducibility of the results in several laboratories. The present work, in compliance with the current standardization and meeting the interests of the various users, researchers or technicians, aims at the design and manufacture of a pin-on-disc wear test bench for testingsamples with varying dimensions obtained by various manufacturing techniques. The premises of the project aim at equipment that guarantees the maintenance of torque and sliding speed throughout the experiment, calibration of the load on the equipment itself, measurement of friction coefficient throughout the test, possibility of dry or fluid testing and damping of the vibrations. A compact prototype was built and validated on the wear of the tribological alumina pair. Accessible and reproducible equipment was obtained based on servo motor drive, synthetic granite table, suspension by cushions for vibration dampingand continuous measurement of friction force during the experiment. For validation analysis, a load of 30 N was applied and a sliding speed of 0.5 m / s, obtaining an average wear rate of 15x10 calibration of the load on the equipment itself, measurement of friction coefficient throughout the test, possibility of dry or fluid testing and vibration damping. A compact prototype was built and validated on the wear of the tribological alumina pair. Accessible and reproducible equipment was obtained based on servo motor drive, synthetic granite table, suspension by cushions for vibration damping and continuous measurement of friction force during the experiment. For validation analysis, a load of 30N was applied and a sliding speed of 0.5 m/s, obtaining an average wear rate of15x10 calibration of the load on the equipment itself, measurement of friction coefficient throughout the test, possibility of dry or fluid testing and vibration damping. A compact prototype was built and validated on the wear of the tribological alumina pair. Accessible and reproducible equipment was obtained based on servo motor drive, synthetic granite table, suspension by cushions for vibration damping and continuous measurement of friction force during the experiment. For validation analysis, a load of 30 N was applied and a sliding speed of 0.5 m / s, obtaining an average wear rate of 15x10 A compact prototype was built and validated on the wear of the tribological alumina pair. Accessible and reproducible equipment was obtained based on servo motor drive, synthetic granite table, suspension by cushions for vibration damping and continuous measurement of friction force during the experiment. For validation analysis, a load of 30 N was appliedand a sliding speed of 0.5 m / s, obtaining an average wear rate of 15x10 A compact prototype was built and validated on the wear of the tribological alumina pair. Accessible and reproducible equipment was obtained based on servo motor drive, synthetic granite table, suspension by cushions for vibration damping and continuous measurement of friction force during the experiment. For validation analysis, a load of 30 N was applied and a sliding speed of 0.5 m / s, obtaining an average wear rate of $15x10^{-6}$ mm ^{3} / Nm and wear volume of 1.2 mm ^{3} after 4000 m of sliding generating an average frictional force of 23 N, results compatible with similar tests.

Sumit Sharma et.al. in (2015) have studied The sliding of metal parts when they are lubricated is important in many mechanical devices covering a wide range of velocities, but the sliding velocity of the lubricated metals which are tribological in behavior. A tribometer is an instrument that measures the tribological properties such as co-efficient of friction, wear volume between two surfaces in contact2, 8. There are various types of tribometer four ball, pin on disc, block on ring, bouncing ball and twin disc. In this paper we have focused or taken aluminum (Al) disc and other mating part is of high speed steel (H.S.S) pin which makes point contact, which is a very common combination. With the help of the apparatus we find different variations such that load and wear rate and time and wear rate variations when load is constant and also pin radius and wear rate variations. In this paper, we calculate the wear rate by using two equations such as Archards equation considering the wear rate with respect to the time and also by using the Archards and Holm equation considering the wear rate with respect to the sliding speed and volume loss. Thesewear testers are generally used in light truck brake pads, on railway tracks, disc brakes.

Parveen Kumar, et.al. in (2017) have studied, Dry and lubricated sliding tribological tests on hypereutectic Al-25Si alloy was performed using a ball- ondisk configuration at room temperature. Hypereutectic Al-25Si alloy were prepared by rapid solidification process under T6 condition. Friction coefficient (COF) and wear rate of the alloy were measured under different applied loads ranging from 5–100 N. It is found that the friction coefficient varies with load, first declines (from 5-50 N), then increases (from 50-80 N) and then again decreases (80-100 N). The wear rate of the samples of hypereutectic Al-25Si alloy, first increases and then decreases with increasing the applied normal load. Hypereutectic Al- 25Si alloy presents higher wear rate at 50 N due to the participation of a large amount of needle-like precipitates, but shows low wear rate under high load of 100 N because of the work hardening layer. Worn surface morphologies were analyzed using optical and scanning electron microscope (SEM) coupled with an energy dispersive spectrometer (EDS). The improvements in COF and wear rate were mainly attributed to morphology, size and distribution of Si particles due to its fabrication process. The dominant wear mechanism for hypereutectic Al-25Si alloy was adhesive wear, abrasive wear and plastic deformation.

Jorge Salguero.et.al. in (2018) have studied, One of the main criteria for the establishment of the performance of a forming process by material removal is based on cutting tool wear. Wear is usually caused by different mechanisms, however, only one is usually considered as predominant or the controller of the process. This experimental research is focused on the application of Pin-on-Disc wear tests, in which the tribological interference between UNS A92024-T3 Aluminum–Copper alloy and tungsten carbide (WC–Co) has been studied. The main objective of this study is focused on the determination of the predominant wear mechanisms involved in the process, as well as the characterization of the sliding and friction effects by using SEM and Energy Dispersion

Spectroscopy (EDS) techniques, as applied to WC–Co (cutting tool material)/Al (workpiece material) which are widely used in the aerospace industry. Performed analysis prove the appearance of abrasive wear mechanisms prior to adhesion. This fact promotes adhesion mechanisms in several stages because of the surface quality deterioration, presenting different alloy composition in the form of a Built-Up Layer (BUL)/Built-Up Edge (BUE).

Vidyasri Khadanga, et.al.in (2019) have studied, metals have very wide applications where generation of friction is the major problem. Due to the continuous friction, wear rate increases which leads to deformation of the metals. The pin-on-disc apparatus is used to find the wear rate between the two different metals. In this experiment Aluminium and Mild steel were used. The wear rate and co-efficient of friction were calculated in two metallic configurations. One of the configurations is High Speed Steel (tool) v/s Mild steel (workpiece) and the another one is High Speed steel (tool) v/s Aluminium (workpiece). In this experiment for both configurations the wear rate and coefficient of friction were recorded at the point loads of 20N,30N,40N. Based on the readings it was concluded that mild steel has less wear rate compared to aluminium at all loading conditions.

Ajay Chavan et.al. in (2020) have studied, AISI 52100 hardened bearing steel is popular in many industrial applications due to its excellent wear resistance and high strength.Therefore, a high level of surface integrity of the same is the utmost important requirement to enhance fatigue life. Machining of hardened AISI 52100 steel is difficult because severe plastic deformation and generation of high temperature alter the surface metallurgy of the machined component and hamper the tool life.)e present investigation includes a comparative analysis of surface integrity of AISI 52100 bearing steel during hard turning under different near-dry environments, namely, dry, Minimum Quantity Cooling and Lubrication (MQCL), Compressed Chilled Air by Vortex Tube (CCAVT), and Hybrid Nanofluid Minimum Quantity Cooling and Lubrication (Hybrid NF-MQCL). Soyabean (a vegetable) oil is used as cutting fluid in MQCL and base fluid in Hybrid NF-MQCL environments. To prepare hybrid nanofluid, two different nanoparticles Al2O3 and MWCNT, are used.)e chilled air is generated through a vortex tube.)e surface integrity of AISI 52100 steel was studied in terms of microhardness, the thickness of the white layer,

surface roughness (Ra), and residual stresses. Higher cutting speed and feed show positive and negative correlation on surface integrity of AISI 52100 steel, respectively. Hybrid nanofluid MQCL exhibits the lowest surface roughness (0.34 μm), microhardness (625 Hv0.1), compressive residual stresses (−168 MPa), and thin white layer (0.9 μm) in contrast, and dry machining shows higher surface roughness, microhardness, tensile residual stress, and thick white layer. In comparison, MQCL and CCAVT are found to be intermediate. It is found that hybrid nanofluid MQCL enhances the overall performance of the machined surface as compared to other near-dry techniques.

2.1. Objective of the Study

- ❖ We have found different variations of wear rate with respect to the loads, time, holder pin, and pin radius.
- ❖ We have also successful in achieving our objective or aim to find out the accuracy of our readings, wear tester as compare to the results of the other researchers.
- ❖ We have got the perfect accuracy of the wear rate as compare to the foreign wear tester. We have developed our tester at small scale which gives the perfect values of the wear rate as compare to the large tester machines.
- ❖ Based on the experimental results and plots it was observed that the wear rate of Mild Steel is very low whereas coefficient of friction is high at all time intervals and the loading conditions. Very less material removal is noticed in Alloy Steel .In case of Aluminium the wear rate increases

with the increase in load and time and the coefficient of friction decreases. According to the results and discussions it was concluded that Alloy Steel exhibits less wear rate compared to the Aluminum.

CHAPTER 3

METHODOLOGY

Wear is a process of removal of material from one or both of two solid surfaces in solid-state contact. As the wear is a surface removal phenomenon and occurs mostly at outer surfaces, it is more appropriate and economical to make surface modification of existing alloys than using the wear resistant alloys.

The mathematical formula for finding out the wear rate was given below:

$$\text{Wear Rate} = W1 - W2\ \rho/2\pi RNT$$

Where, $[W1-W2]/\rho$ =Volume of material

removed, $2\pi RNT$ = Sliding distance

Friction is a force resisting relative motion, which may occur at the interface between the bodies, but may also occur within the bodies.

Mathematically, Co-efficient of friction defines that the frictional force is directly proportional to normal force. Mechanically it shows the relationship between forces which are collaborated with different materials. It is a dimensionless parameter and means that the physical matter doesn't changes by the direction of force.

$$F = \mu N$$

$$\mu = F\ N$$

Where, F = Friction Force

μ = Co-efficient of Friction

N= Normal Force

3.1. Materials and Methods:

In this study, AISI 52100 bearing steel was used as work piece material; its chemical composition is reported in Table 1. AISI 52100 bearing steels are commonly used in applications requiring high hardness and abrasion resistance. The bearing steels are working under dynamic loads in service conditions and their toughness properties become important. In order to provide the desired mechanical properties, various heat treatments (austenizing, quenching and tempering) are usually applied.

Table 3.1: Chemical composition of AISI 52100 steel

Fe	C	Si	Cr	S	Mn	P
96.89	1.01	0.22	1.41	0.05	0.4	0.021

3.1.1. Apparatus:

Tribometer is a device which is used to measure tribological properties like Wear, Friction and Lubrication. Tripmeter is available in various types which are given below.

1. Pin-on-disc Tribometer,
2. Ball-on-disc Tribometer,
3. Ring-on-Ring Tribometer,
4. Reciprocating Tribometer,
5. Four ball Tribometer etc.

Pin-on-disc Tribometer: Pin on disc consists of a stationary pin that is normally loaded against a rotating disc. The pin can have any shape to simulate a specific contact. In this apparatus the wear rate of disc or tool can be measured.

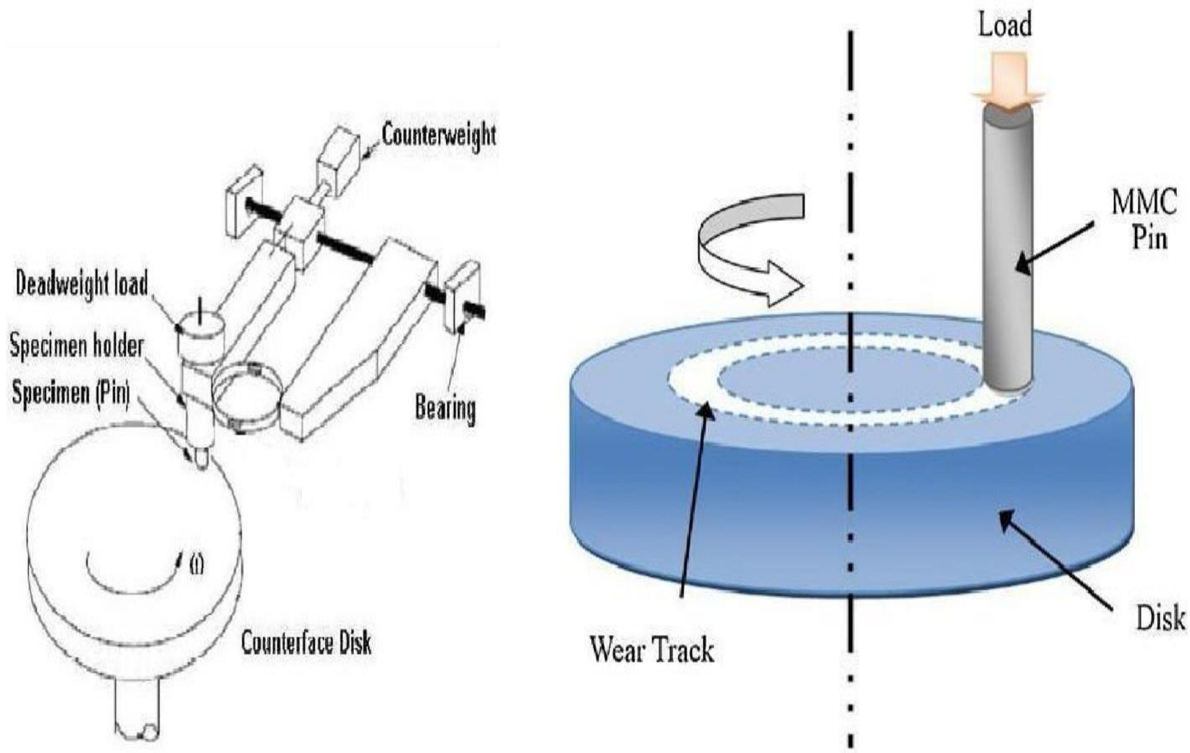

Fig. 3.1 Schematic views of the pin-on-disk apparatus

In Figure, indentation tool was used in pin-on-disc apparatus. Single point cutting tools were used to remove material by means of one cutting edge. Cutting tool material must be harder than the material which is to be cut, and the tool must be able to withstand the heat generated during the metal cutting process. . The Table 3.2: shows the type of tool used and other specifications of tool.

Table 3.2 Tool Specification.

TITLE	DESCRIPTION
Name of the tool	Single point Cutting tool
Tool material	High Speed Steel
% of carbon	0.1%

The work piece used in the pin-on-disc Tribometer is circular disc. It should have a capable of withstanding the heat generation during the process and also it should must have good strength, hardness and ductile nature.

3.1.2 Wear Parameters:

The variables involved in wear test are:

- AISI 52100 alloy steel
- Normal load
- Sliding speed
- Lubrication

Wear behavior of the fabricated samples is combined affected by the above parameters. The effect of each individual parameter is studied in these experiments.

3.1.3 Test Setup:

This apparatus, figure 1, is model of Pin on Disc Tribometer working at very low rpm, at constant sliding velocity and fixed radius of wear circle. This apparatus can be used in lab to perform wear testing of given metal and study the effect of lubrication of different lubricants on that particular metal under different loading conditions. The specific wear rate is calculated, the specific wear rate helps in determining wear resistance provided by the metal under running conditions.

Fig.3.2. Test setup Pin on Disc

The setup consists of a frame, ring arrangement, pin rod (cast iron) and metal discs(Aluminium and mild steel) supported on a board. The disc is rotated by a DC motor of 746 W, with 3 rpm; the weight is applied on the disc by placing the weights on the pan, to generate a wear pattern on the surface of the disc. The balancing of the rod holding the pin is done by the copper string and a metal wire having high tensile strength. The depth of penetration is measured using a range meter setup consisting of micro controller, and a LCD display. For lubrication HP racer 2 stroke engine oils used.

3.1.4 Wear Test:

Abrasive Wear Test Apparatus: Test up used in the study of wear test is capable of creating reproducible abrasive wear situation accessing the abrasive wear resistance of the prepared samples. It consists of a pin on disc, loading panel and controller.

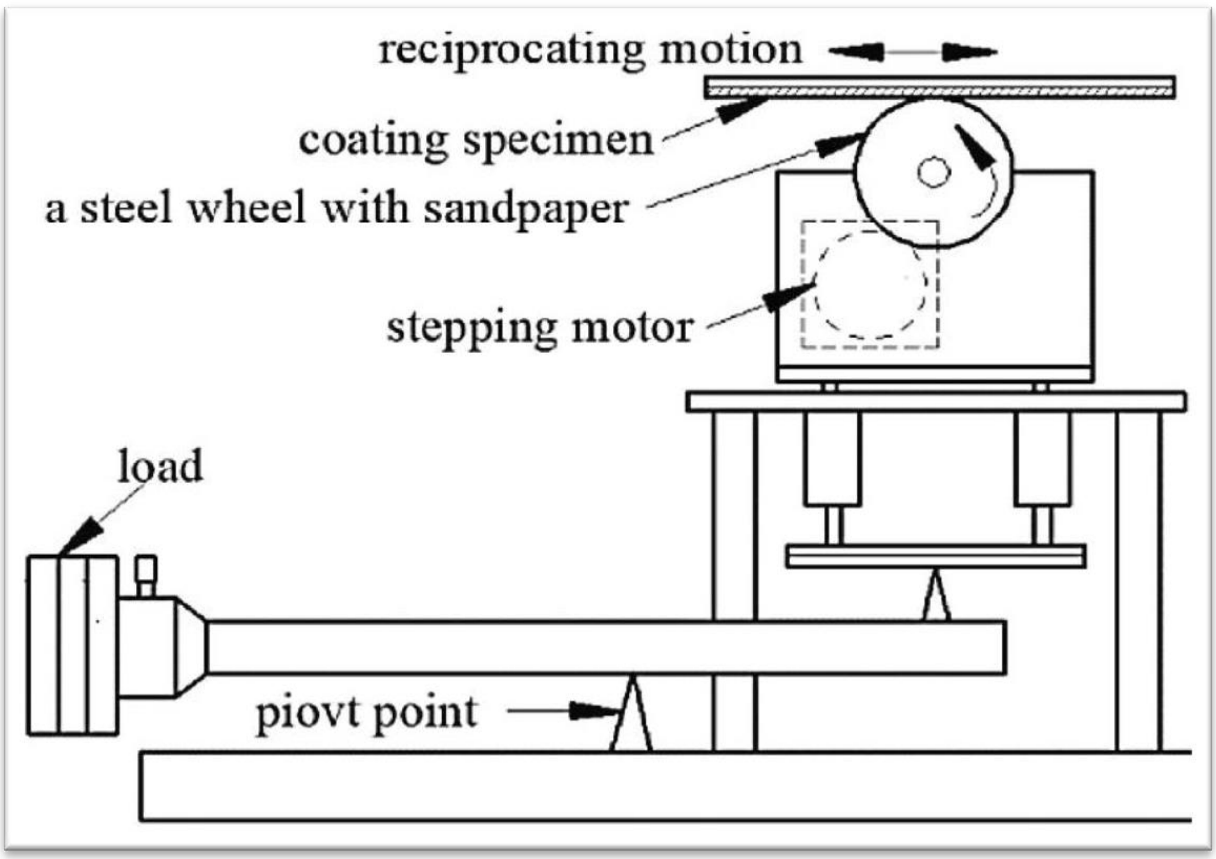

Fig.3.3. Abrasive wears test apparatus.

All the test were carried out using a "Ducom friction and wear monitor" machine with both normal and lubricated condition. The normal condition has 50-60% relative humidity and a temperature of 28-32:C. The mass loss of the specimen after each test was estimated by measuring the height loss of the specimen due course of the experiment. The mass loss would be the heightloss multiplied by the area of cross section of the sample and thedensity of the sample. Care has been taken to clean up the sample before and after each testto prevent any form of corrosion on the surface. Abrasive paper of required grit size(220 µm optimised for the Al-Si sample) is cut into circular shape so as to fit in the ground steeldisc and pasted on it with a proper adhesive ensuring no slide or detachment. The specimenwas held steady and stationary with a holder of the apparatus and the required normal load was applied through lever mechanism. The sliding radius was kept at 80 mm for all tests concerned. The table 3.3. Shows the specification of wear and friction monitor.

Table 3.3 Specification of wear and friction monitor.

Parameter	Unit	Minimum	Maximum
Wear Disk	Mm	100x6	-
Disk speed	RPM	10	800
Pin diameter	Mm	2	10
Pin length	Mm	10	50
Ball diameter	Mm	10	-
Wear track diameter	Mm	10	80
Normal Load	N	0	100

3.1.5 Wear Measurement:

Wear rate was estimated by measuring the mass loss in the specimen after each test and mass loss, Δm in the specimen was obtained. We can calculate the mass loss by measuring the height loss (Δh) in each experiment, the area of cross section (A) of sample and the density (ρ) of the alloy by using the realtion,

$$\Delta m = \Delta h \times A \times \rho$$

Cares have been taken after each test to avoid interaction of wear debris in the specimen. Wear rate which relates to the mass loss (Δm) and sliding distance (L) was calculated usingthe expression,

$$W = \Delta m / L$$

The friction force was measured for each pass and then averaged over the total number of passes for each wear test. The average value of co-efficient of friction, μ of composite was calculated from the expression

$$\mu = F_f / F_n$$

where Ff is average friction force and Fn is applied load.

For characterization of the abrasive wear behavior of the composite, the specific wear rate is employed. This is defined as the volume loss of the composite per unit sliding distance and per unit applied normal load. Often the inverse of specific wear rate expresses in terms of the volumetric wear rate as

$$W_s = W_v / V_s F_n$$

Where Vs is the sliding velocity.

3.1.6 Lubricated wear test:

In this case wear of samples were done in presence of some lubricating medium like engine oil of grade SAE 20W-40. The respective calculations can be done for this condition. The same operating conditions as in dry wear tests were applied except that a continuous flowof the lubricant was supplied to the alloy-abrasive paper interface.

3.2 Description of the parts of wear test pins on disc

3.2.1 Regulator or Controller

Regulator of a direct current motor is used to regulate and control the speed of motor. It has ammeter to measure current and voltmeter to measure volt attached to it. The characteristic features of regulator are:

Regulated Voltage – 0-260 V, Least Count – 2V

The technical parameters of Ammeter are:

Current Range: 0 – 10 ampere

Least Count: 0.4 ampere

The technical parameters of Voltmeter are:

Voltage Range: 0– 300V,

Least Count: 20 V

Fig 3.4 Regulator

3.2.2: Frame

The main frame is just like chassis to the engine, it hold all the parts such as motor, shaft , pulley, load cell , bearing and all its related attachment. The main frame used in the design.

The dimensions of the main frame are as follows:

Length – 105 cm, Width – 21 cm

Dimensions of angular frame are as follows:

Length – 115 cm Width – 35 cm

Fig 3.5 Frame

3.2.3 Grinding Wheel:

A grinding wheel used in the design as an abrasive media to produce abrasive wear on the specimen selected. The dimensions of the grinding disc are as follows:

Diameter – 20.32 cm

Fig.3.6 grinding wheel

3.2.4 Speed of Grinding Wheel

Generally all the abrasive processes are performed with the wheel speed in between the range of 1500-2000 rpm with the maximum work speed from 0 to 60 m/min.

3.2.5 Shaft

Two shafts were used, the first shaft connects motor to the abrasive disc and second shaft connects acrylic disc to screw jack. Load is applied with help of second shaft, it pushes the specimen against the rotating abrasive disc. An attachment of load cell is fitted on second shaft to measure the applied load. The dimensions of the shaft are as follows:

Diameter – 30mm

Length – 70 cm

3.2.6 Bearing

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may *prevent* a motion by controlling the vectors of normal forces that bear on the moving parts. Most bearings facilitate the desired motion by minimizing friction. Bearings are classified broadly according to the type of operation, the motions allowed, or to the directions of the loads (forces) applied to the parts.

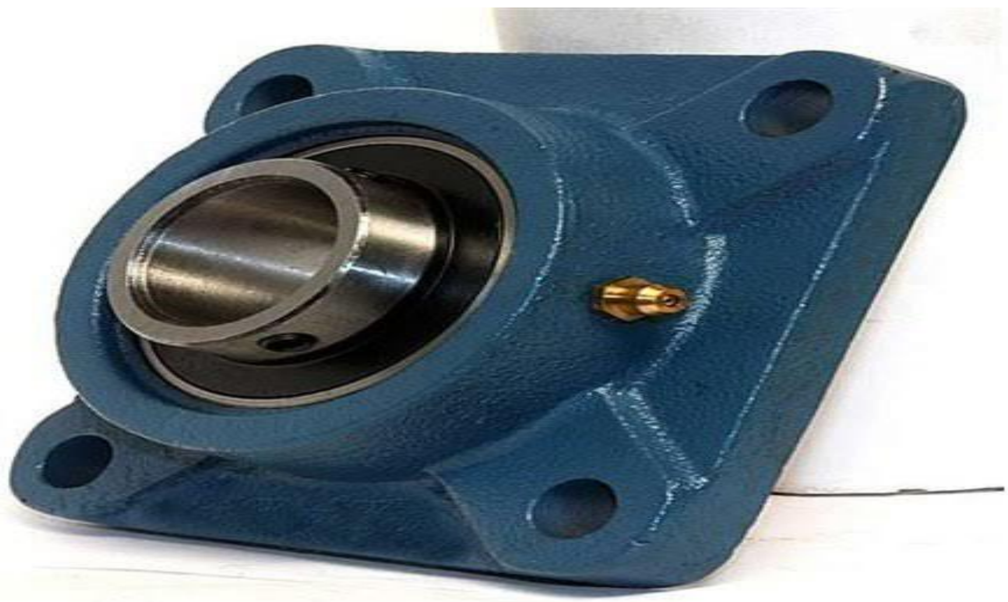

Fig 3.7 Bearing

3.2.7 DC Motor

A DC motor is any of a class of rotary electrical motors that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current in part of the motor.

The D.C. Motor having following specifications:

Power – 1 H.P,

Rotation – 1rpm to 3000 rpm

Fig 3.8 DC Motor

3.3 Complete picture of the pin on disc setup

By the complete attachment of the sab assemblies and parts we simply gets the complete test pin on disc which is simply use for the measurement of the amount of wear rate. All the assemblies and fasteners are properly attached so that experimental run properly.

Fig 3.9 Pin on disc setup

3.4 Test procedure:

Steps to be followed in order to conduct the experiment are:-

Place the test metal disc on DC motor.

- Place the pin over the disc.
- Run the motor at full speed and ON the range meter.
- Place the weights in the pan and observe the wear pattern on disc made by pin. Simultaneously, note the reading from range meter.
- Measure the radius of wear loss made by pin on the disc.
- Take the highest value of depth of penetration and plot the graph between depth of penetration and applied load (Dry testing).

Wear Calculation-

- ❖ Area

Cross sectional Area, $A = \pi r^2$

- ❖ Volume loss

Volume loss = Cross sectional Area x Height loss

- ❖ Wear rate

Wear rate = Volume loss / Sliding distance

- ❖ Wear resistance

Wear resistance = 1/ Wear rate

- ❖ Specific wear rate

Specific wear rate = Wear rate/load

- Plot the graph between wear rate and applied load.
- Apply lubricant on the disc.

3.5 Specimen Used

AISI52100 has been used to test the appropriate wear.

Fig 3.10(a) Test specimen of alloy steel before experiment

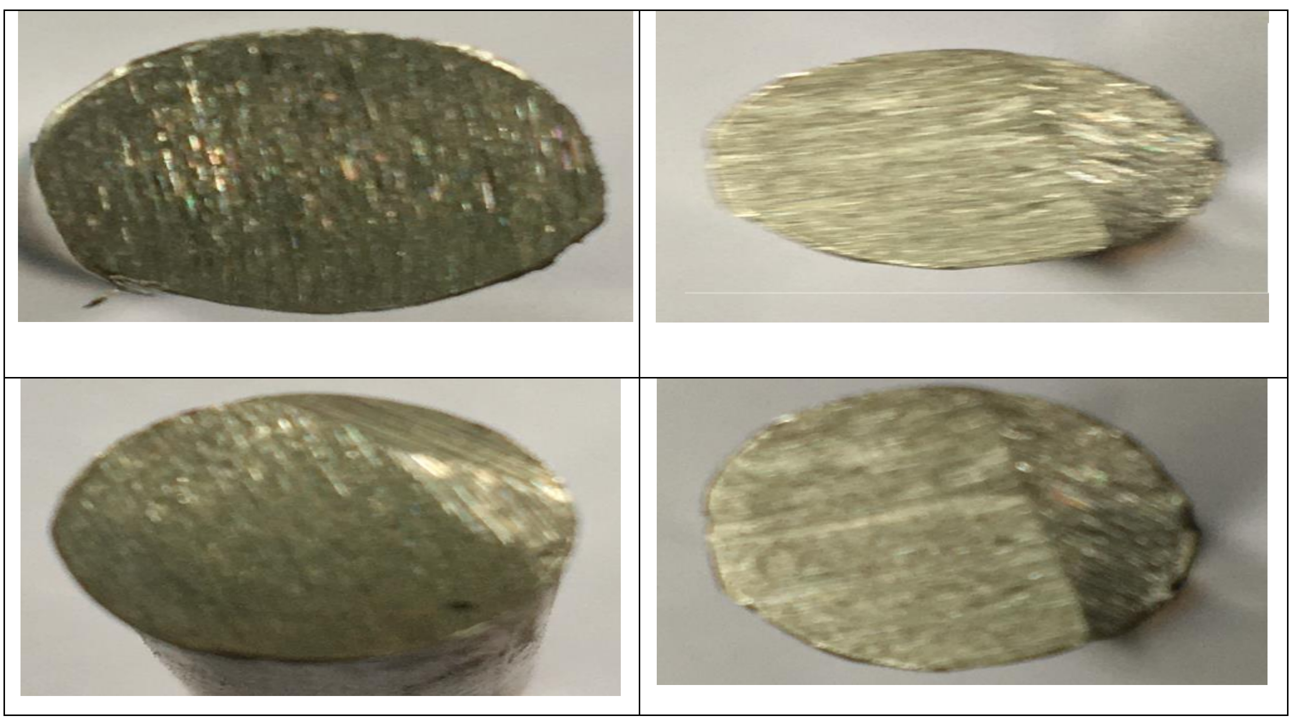

Fig 3.10(b) Test specimen of alloy steel after experiment

3.6 Weighing machine

The weighing machine used in the design to calculate mass loss (wear) of the specimen. The weighing machine used had following parameters: Least Count – 0.001gm

Fig 3.11 Weighing machine

3.7 Wear Characterization

The following method was adopted for wear wear characterization.

- Selection of applied load and the position of the specimen.
- Speed of grinding wheel.

3.7.1 Selection of Applied Load and Position of the Specimen

The following loads were selected for present objective

1. 5N
2. 10N
3. 15N

3.7.2 Speed of grinding wheel

The speed of grinding disc varies from 250 rpm, 500 rpm, and 750 rpm for particular loading conditions.

1. 250rpm
2. 500rpm
3. 750rpm

CHAPTER 4

Experimental Analysis

Whole analysis is mainly considering three important factor which are as follows:

- Applied Load condition (N) (5N, 10N, 15N)
- Determination of mass loss (gm.)
- Speed of grinding wheel (RPM) (250 RPM, 500 RPM, and 750 RPM.)

The complete analysis is comes under these factor. First we consider a constant orientation angle and change the speed of grinding wheel under varying loading condition.

Table 4.1 Mass load data for 5 N load

S.NO.	SPECIMEN	SPEED OF WHEEL(RPM)	MASS LOSS (gm)	MEAN OF THE MASS LOSS(gm)
1	1	250	0.026	0.05025
2	2	250	0.053	
3	3	250	0.064	
4	4	250	0.058	
5	1	500	0.223	0.1785
6	2	500	0.141	
7	3	500	0.138	
8	4	500	0.212	
9	1	750	0.221	0.2215
10	2	750	0.237	
11	3	750	0.175	
12	4	750	0.253	

Table 4.2 Mass Loss Data 10N load

S.NO.	SPECIMEN	SPEED OF WHEEL (RPM)	MASS LOSS (gm)	MEAN OF THE MASS LOSS (gm)
1	1	250	0.0698	0.0773
2	2	250	0.0731	
3	3	250	0.0866	
4	4	250	0.0798	
5	1	500	0.1868	0.1840
6	2	500	0.1935	
7	3	500	0.1761	
8	4	500	0.1797	
9	1	750	0.2376	0.2332
10	2	750	0.2338	
11	3	750	0.2259	
12	4	750	0.2358	

Table 4.3 Mass Loss Data 15N load

S.NO.	SPECIMEN	SPEED OF WHEEL (RPM)	MASS LOSS (gm)	MEAN OF THE MASS LOSS (gm)
1	1	250	0.083	0.0905
2	2	250	0.100	
3	3	250	0.091	
4	4	250	0.088	
5	1	500	0.1985	0.1977
6	2	500	0.2032	
7	3	500	0.1955	
8	4	500	0.1938	
9	1	750	0.2507	0.2469
10	2	750	0.2366	
11	3	750	0.2486	
12	4	750	0.2519	

4.1 Variation of Wear Rate for 5 N Load

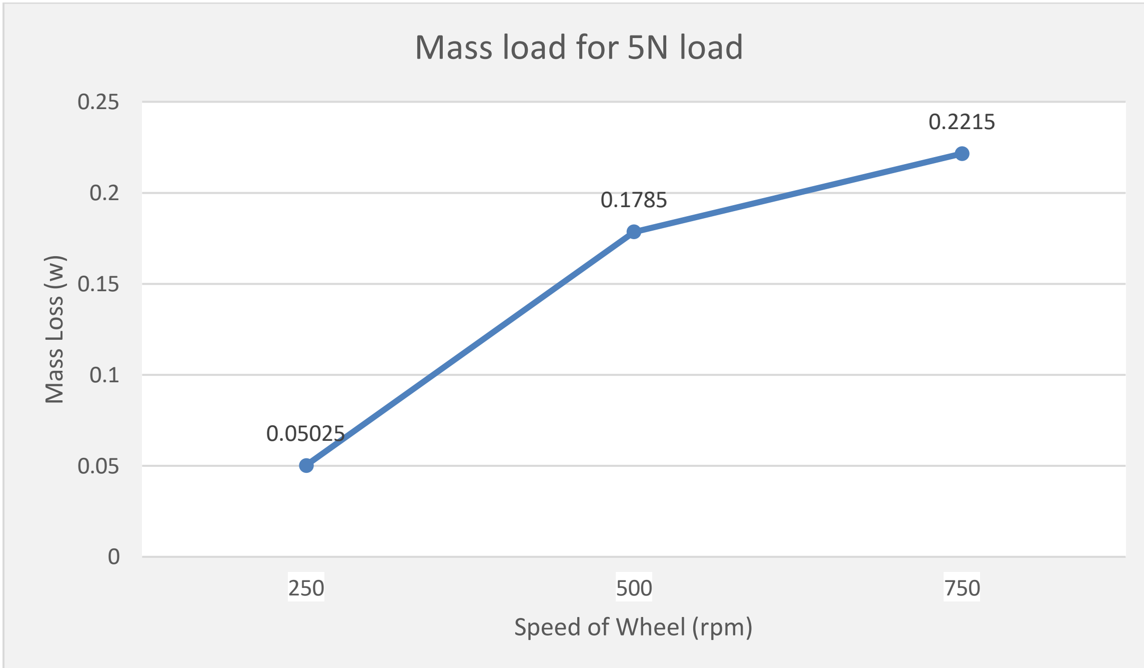

Fig 4.1 Variation of wear rate with different speed of grinding wheel for 5N load

4.2 Variation of Wear Rate for 10 N Load

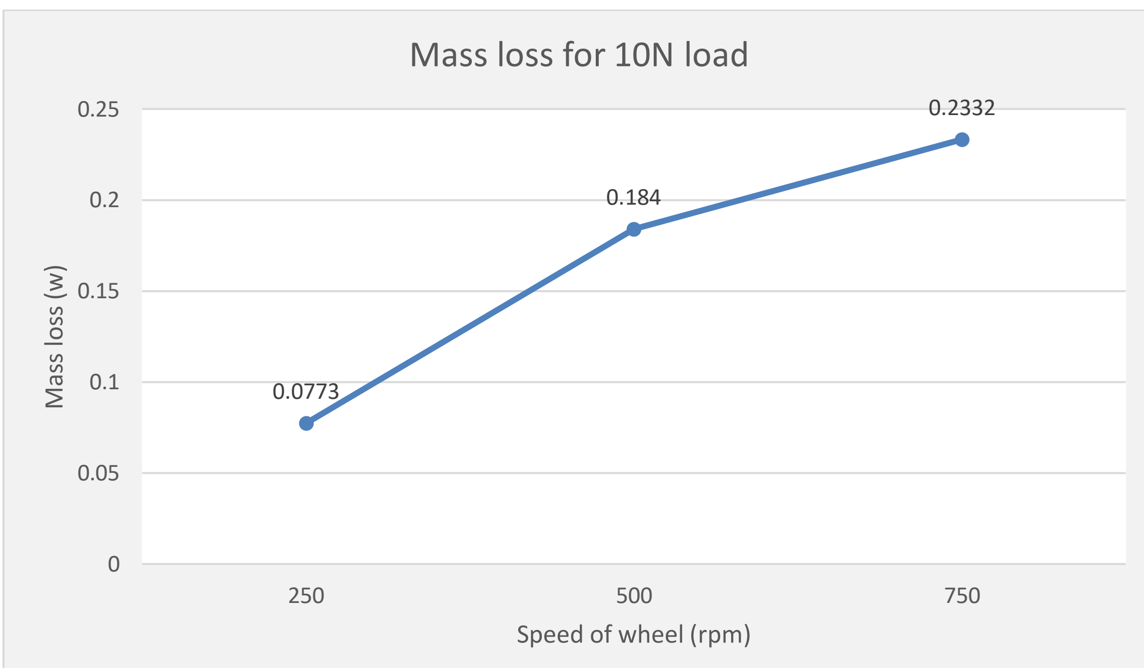

Fig 4.2 Variation of wear rate with different speed of grinding wheel for 10N load

4.3 Variation of Wear Rate for 15 N Load

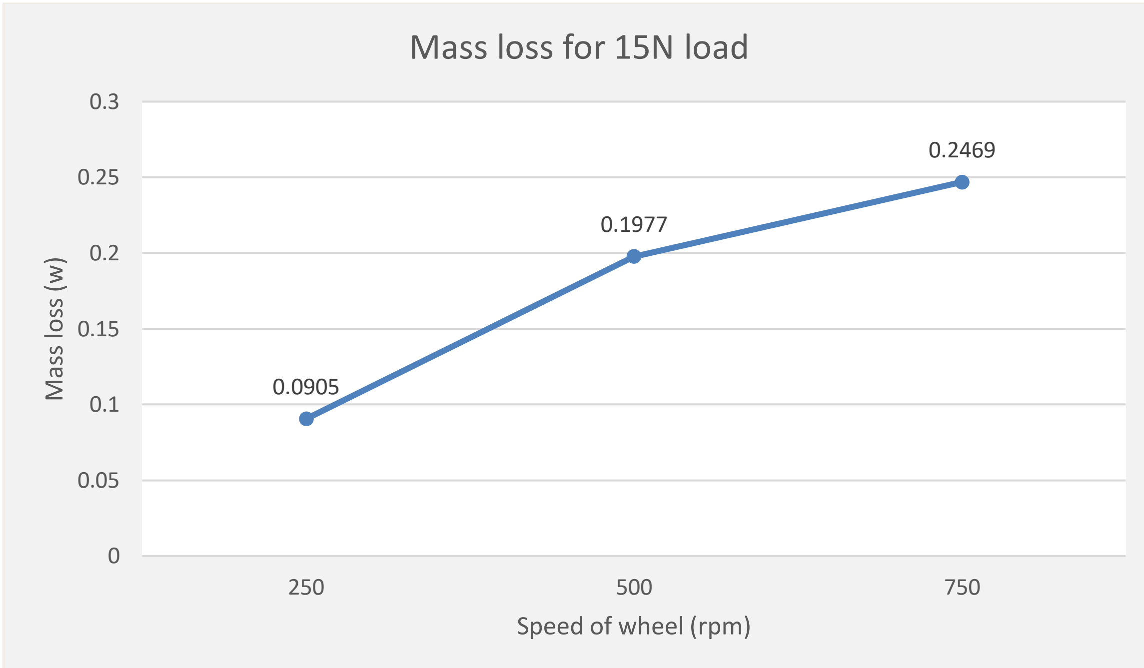

Fig 4.3 Variation of wear rate with different speed of grinding wheel for 15N load

4.4 SPEED OF GRINDING WHEEL AT 250 RPM

When we simply consider 250 rpm speed of grinding wheel with three different loading condition then approximately 03 reading are taken.

Table 4.4 Mass loss (w) at 250 rpm

S.NO.	LOAD(N)	MASS LOSS (gm)
1	5	0.0502
2	10	0.0773
3	15	0.0905

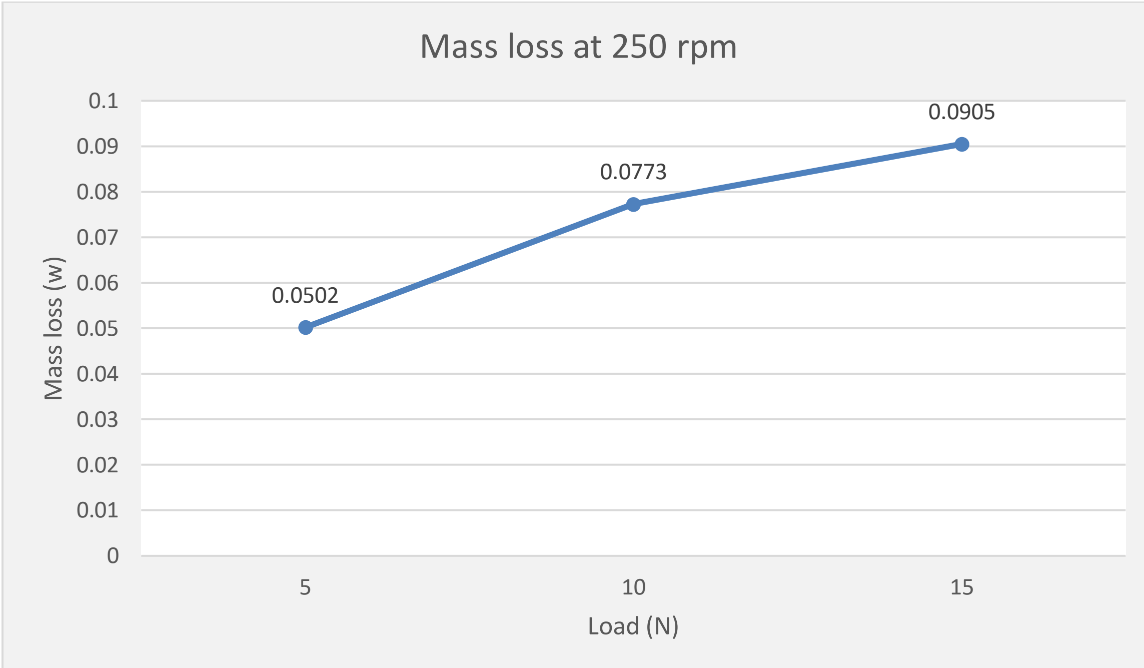

Fig 4.4 Variation of wear rate with different loading condition at 250 rpm

4.5 SPEED OF GRINDING WHEEL AT 500 RPM

When we simply consider 500 rpm speed of grinding wheel with three different loading condition then approximately 03 reading are taken.

Table 4.5 Mass loss (w) at 500 rpm

S.NO.	LOAD(N)	MASS LOSS (gm)
1	5	0.1785
2	10	0.1840
3	15	0.1977

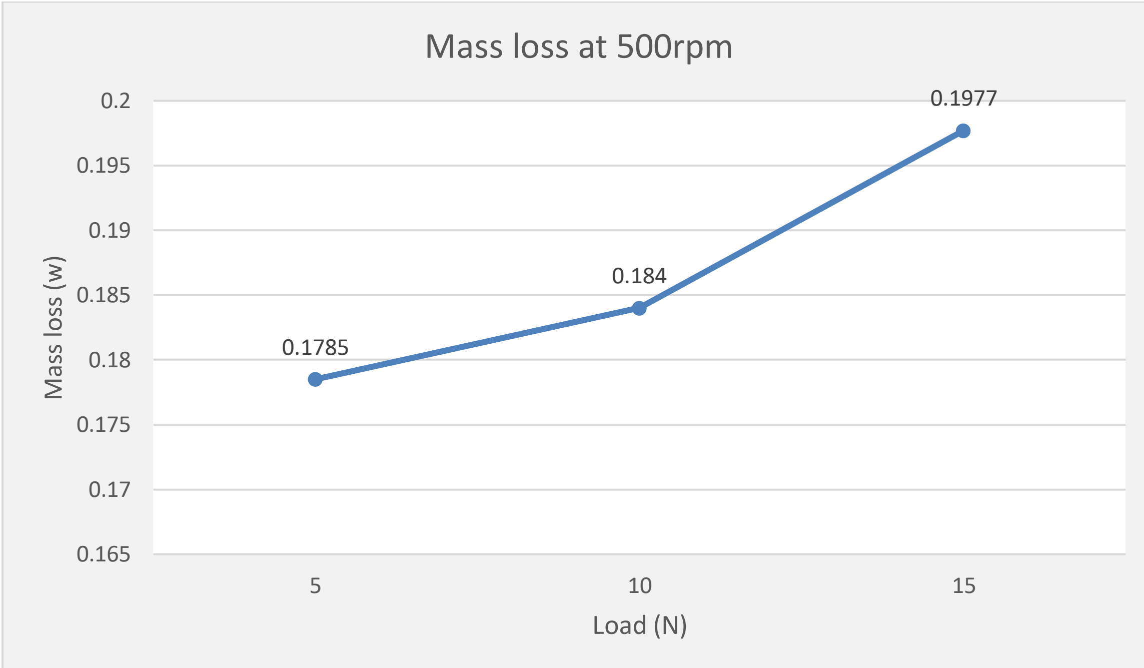

Fig 4.5 Variation of wear rate with different loading condition at 500 rpm

4.6 SPEED OF GRINDING WHEEL AT 750 RPM

When we simply consider 750 rpm speed of grinding wheel with three different loading conditions then approximately 03 reading are taken.

Table 4.6 Mass loss (w) at 750 rpm

S.NO.	LOAD(N)	MASS LOSS (gm.)
1	5	0.2215
2	10	0.2332
3	15	0.2469

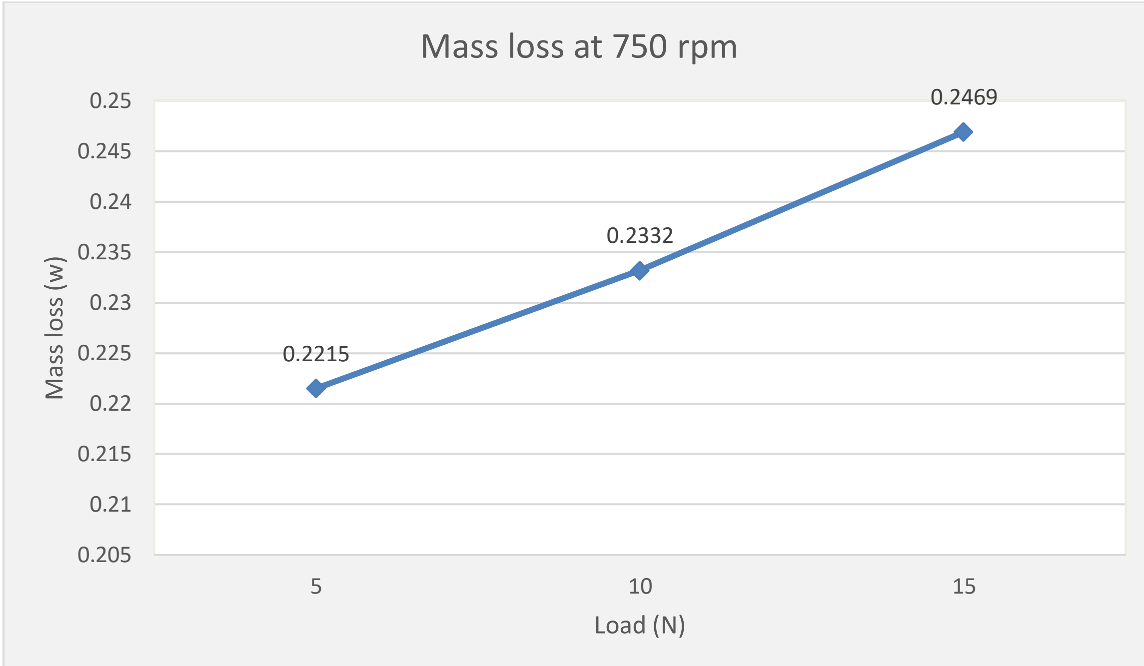

Fig 4.6 Variation of mass loss with different loading condition at 750 rpm

CHAPTER 5

RESULT AND DISCUSSION

5.1 EFFECT OF SPEED OF GRINDING WHEEL ON WEAR

- From Fig 4.1 it is observed that as the speed of grinding wheel changes from 250 rpm to 750 rpm, the wear mass (Wt. Loss) increases from 0.05025 gm to 0.2215 gm when applied load is 5 N.
- From Fig 4.2 it is observed that the wear mass follows as the same pattern as in graph 4.1 the wear mass (Wt. Loss) increases from 0.0773 gm to 0.2332 gm as the speed of grinding wheel from 250 rpm to 750rpm, when applied load is 10 N.
- Similarly from Fig 4.3 it is observed that the wear mass (Wt. Loss) increases from 0.0905 gm to 0.2469 gm as the speed of grinding wheel from 250 rpm to 750rpm, when applied load is 15 N.

5.2 EFFECT OF LOAD ON WEAR

- From Fig 4.4 it is observed that the wear mass increases from 0.0502 gm to 0.0905 gm as the applied load on the specimen increases from 5 N to 15 N, when speed of grinding wheel is at 250 rpm.
- From Fig 4.5 it is observed that the wear mass increases from 0.1785 gm to 0.1977 gm as the applied load on the specimen increases from 5 N to 15 N, when speed of grinding wheel is at 500 rpm.
- From Fig 4.6 it is observed that the wear mass increases from 0.2215 gm to 0.2469 gm as the applied load on the specimen increases from 5 N to 15 N, when speed of grinding wheel is at 750 rpm.

CHAPTER 6

Conclusion

After successful experiential work related to investigation of mass loss due to frictional effect developed due to applied load, following conclusion can be drawn.

1. Maximum wear occur when the test specimen is held at 750 rpm for given applied load.

2. Minimum wear occur when the test specimen is held at 250 rpm for given applied load.

3. According to random analysis it has been observed that loading condition for selected specimen, rotational speed 250 rpm and time of 1 minute because there is less wear rate.

4. Wear is directly proportional to the applied load and rpm also.

5. Maximum wear occur at maximum loading condition of 15N

6. Minimum wear occur at minimum loading condition of 5N.

7. Wear is seen to increase at higher sliding speed and at higher applied load

8. In case of lubricated condition the specimen’s shows lower amount of material loss.

CHAPTER 7

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