STUDY AND ANALYSIS OF WEAR CHARECTERIZATION OF ALUMINUM 5652 ALLOY AND ALUMINUM UNDER DRY FRICTION BY USING PIN ON DISC APPARATUS

A Thesis

Submitted

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF TECHNOLOGY

in

Mechanical Engineering

With specialization

in

"Production and Industrial Engineering"

Submitted by

Mohd. Arish

(Enrollment No. 1900100273)

.

Department of Mechanical Engineering

INTEGRAL UNIVERSITY, LUCKNOW, INDIA

September, 2021

CERTIFICATE

This is to certify that **Mr. Mohd. Arish** (Enroll. No. 1900100273) has carried out the research work presented in the thesis titled **"Study and analysis of wear characterization of aluminium 5652 alloy and aluminium under dry friction 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.

(iii) The thesis fulfills the requirements of the norms and standards prescribed by the University Grants Commission and Integral University, Lucknow, India.

(iv) No published work (figure, data, table etc) has been reproduced in the thesis without express permission of the copyright owner(s).

Therefore, I deem this work fit and recommend for submission for the award of the aforesaid degree.

Signature of Supervisor

Dr. Mohd. Shadab Khan

Associate Professor

Department of Mechanical Engineering,

Integral University, Lucknow

Date:10/09/2021

Place: Lucknow

CERTIFICATE

This is to certify that **Mr. Mohd. Arish** (Enroll. No. 1900100273) has carried out the research work presented in the thesis titled **"Study and analysis of wear characterization of aluminium 5652 alloy and aluminium under dry friction 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.

(iii) The thesis fulfills the requirements of the norms and standards prescribed by the University Grants Commission and Integral University, Lucknow, India.

(iv) No published work (figure, data, table etc) has been reproduced in the thesis without express permission of the copyright owner(s).

Therefore, I deem this work fit and recommend for submission for the award of the aforesaid degree.

Signature of Co-Supervisor
Er. Abdul Ahed Khan
Assistant Professor
Department of Mechanical Engineering,
Integral University, Lucknow
Date: 10/09/2021
Place: Lucknow

DECLARATION

I hereby declare that the thesis titled "**Study and analysis of wear characterization of aluminium 5652 alloy and aluminium under dry friction by using pin on disc apparatus**" is an authentic record of the research work carried out by me under the supervision of Dr. Mohd. Shadab Khan, Department of Mechanical Engineering, and co-supervision of Er. Abdul Ahed Khan, Department of Mechanical Engineering. 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:

Signature

Name **Mohd. Arish**

Enroll. No. **1900100273**

ACKNOWLEDGEMENT

First of all I am highly indebted and thankful, the almighty God, the most merciful and benevolent to all, who taught men that which he knew hot and bestowed the men with epistemology and gave him the potential to ameliorate the same. It is my pleasant duty to acknowledge the help received from several individuals during the work

I wish to express my profound gratitude, respect and honour to my supervisor & co-supervisor **Dr. Mohd Shadab Khan**, Associate Professor **& Er. Abdul Abed Khan**, Assistant Professor, Department of Mechanical Engineering. Integral University. Lucknow, for their illuminative and precious guidance, constant supervision, critical opinion and timely suggestion, constant useful encouragement and technical tips which has always been a source of inspiration during the preparation of dissertation

I would also like to thank the rest of thesis committee, Prof**. Dr. Prem Kumar Bharti** (HOD Department of Mechanical Engineering), my Dissertation Incharge Dr. Mohd Anas, Associate Professor, Entire Faculties and staff of Department of Mechanical Engineering for their supports, encouragement and providing me the opportunities while working on this exciting research.

I will be failing in my duties if I miss to express my profound and deepest sense of gratitude to my beloved parents and other members of family and friends for their keen interest in my studies, immense support and encouragement, without which it was impossible to complete this dissertation.

I also place on record my sense of gratitude to one and all who directly or indirectly. Have lent their hand in this thesis.

Mohd. Arish

Roll. No. 1901301004

LIST OF FIGURES& TABLES

TABLE OF CONTENTS

ABSTRACT

To evaluate the wear behavior and wear characteristics of aluminium 5652 and aluminium at four different speed of rotating wheel disc (250rpm, 300rpm, 400rpm, and 500rpm) has been performed on wear test rig apparatus through pin on disc setup. In this work techo-meter has been used for checking the rotation of shaft at different voltage and found maximum rpm at 200V. The effect of speed of alloy disc and applied loading condition (10N, 20N, and 30N) under constant orientation angle on the weight has been determined.

The result of the study revealed that as the speed of grinding wheel disc and load increases the wear rate of the aluminium specimen. The maximum wear occurs at 500rpm speed of wheel disc for 30N whereas minimum wear occurs at 250 rpm speed of alloy wheel for 10N and maximum wear occur at 500rpm at maximum loading 30N.

CHAPTER 1
INTRODUCTION

1.1 General

Tribology is the science of wear, friction lubrication. Tribology includes boundary layer interaction both between solids, liquid and gases. Tribology encompasses the entire field of friction and, including lubrication. Tribology is highly interdisciplinary, drawing on many academics fields, including physics, chemistry, material science, mathematics, biology and engineering. People who work in the field of tribology are referred to as tribologist. The fundamental objects of study in tribology are tribosystem, which are physical system of contacting surfaces in lubricated tribosystem, contact stress can create tribofilms [1].

Aluminum and its alloy is an important class of material for tribological application due to its low density and high thermal conductivity. Aluminum based alloys is widely used in aircraft, vehicle body, and various automotive industry. Therefore the study of characteristics of aluminum based alloys has become wide range of research area. also the demand of aluminum alloy is increased due to its superior properties such as hardness, tensile strength, low coefficient of thermal expansion, good corrosion resistance. Among wide variety of aluminum based alloys we used Al5652 alloy. The two main components of Al5652 is magnesium (mg), and chromium (cr) .which is added to aluminum to makes its structural strength, toughness and melting point is perfect. Aluminum based alloys has replaced steel in several application due to its high strength to weight ratio and corrosion resistance. Aluminum based alloys gives low coefficient of friction. coefficient of friction is a dimensionless quantity [2]

1.2 Wear

Wear may be define as a damaging a solid surfaces of body and losses of material due to its relative motion between the surfaces. It is quantitatively measured in terms of mass, or volume loss from their its contacting surfaces. Due to loss of material from its surfaces wear debris is produced. Chemical wear has a similar character but on a smaller scale. Subsequently, perhaps immediately, this debris is expelled from the contact zone and the process of wear is observed [3].

Wear may include loss at the interface between two sliding surfaces. However, plastic deformation such as yield stress is excluded from the wear definition if it doesn't incorporate a relative sliding motion and contact against another surface despite the possibility of material removal, because it then lacks the relative sliding action of another surface.

There are three stages of wear in any components.

- Primary stages: In which the material contact is necessary .wear may be high or low at this stage.
- Secondary stages: In which the steady rate of ageing occurs. This stage is the most operational period of component life.
- Old age: In which components life failure rate is very high.

1.2.1 Wear types

Five types of wear are as follows:

1-Adhesive wear

2-Abrasive wear

3-Fretting

4-Erosive wear

5-Fatigue surfaces

Adhesive wear:

Adhesive wear is a kind of wear which occurs due to localized bonding between contacting solid surfaces leading to material loss from either surfaces .The contact load is sustained only by a small area when two mating surfaces are presses against each other. By the use of hard coating with low coefficient of friction and lubricants, adhesive wear may be decreased. Adhesive wear occurs due to the relative motion of the contacting surfaces and cohesive forces between the materials in contacts [4].

Adhesive wear occurs when the atomic forces occurring between the materials surfaces under relative load are stronger than the inherent material properties of either surfaces .Continues motion of the surfaces causes breaking of the bond junction. Each time a bond junction is broken, a wear particles is formed, usually from the weaker components [5]. (Fig.1.1)

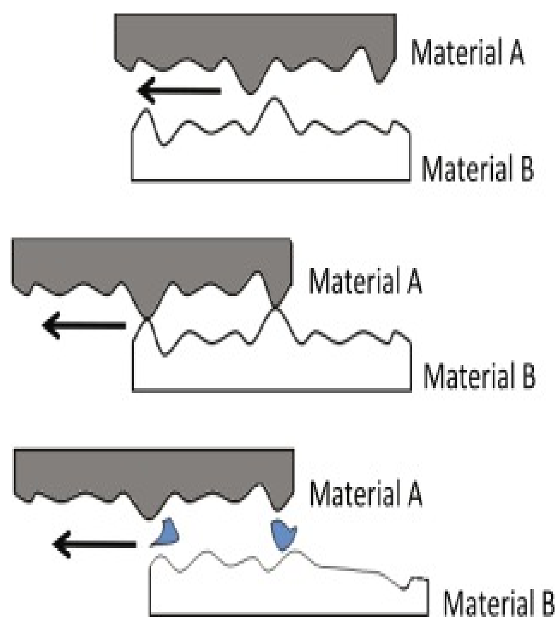


Fig.1.1 Adhesive wear

Abrasive wear :

Abrasive wear occurs when a hard rough surfaces slides across a softer surfaces, in this case, wear is defined as a damage to a solid surfaces that generally involves progressive loss of material and is due to relative motion between that surfaces andd a contacting substance (ASM,1998;ASTM 1987). Abrasive wear is commonly classified according to the type of contact and the contact environment, the type of contact determine the mode of abrasive wear (ASM, 1998).The two modes of abrasive wear are known as two-body and three-body abrasive wear.Two-body abrasive wear occurs when on surface cuts material away from the other surfaces, Three-body wear occurs when particles are not constrained, but are free to roll and slide down a surface (AS, 1998; Peterson, 1980). A Figure shown below Fig.1.2 [6]

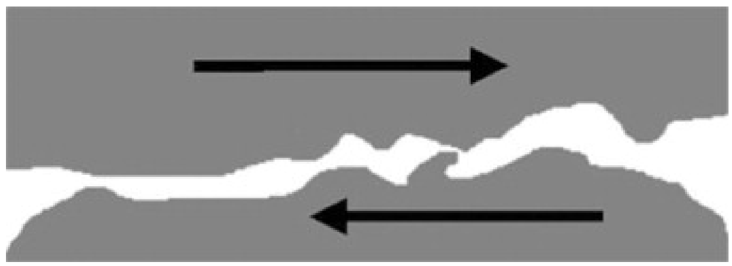


Fig.1.2 Abrasive wear

Modes of Abrasive Wear

The way the grits pass over the worn surface determines the nature of abrasive wear. The literature denotes two basic modes of abrasive wear:

- Two-body and
- Three-body abrasive wear.

1. **Two body abrasion** - Two-body abrasive wear is exemplified by the action of sand paper on a surface. Hard asperities or rigidly held grits pass over the surface like a cutting tool . In this condition, one surface is harder than the other rubbing surface as shown in fig1.3. Examples in mechanical operations are grinding, cutting, and machining.

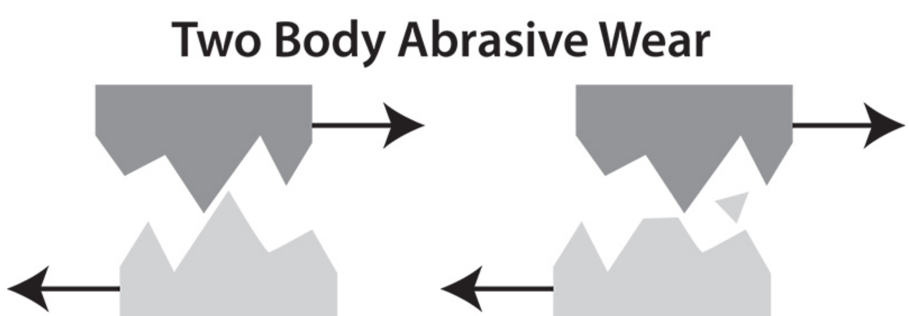


Fig.1.3 Two body abrasion

2. **Three body abrasion** - In three-body abrasive wear the grits are free to roll as well as slide over the surface, since they are not held rigidly. In this case a third body, generally a small particle of grit or abrasive, lodges between the two softer rubbing surfaces, abrades one or both of these surfaces, as shown in fig.1.4

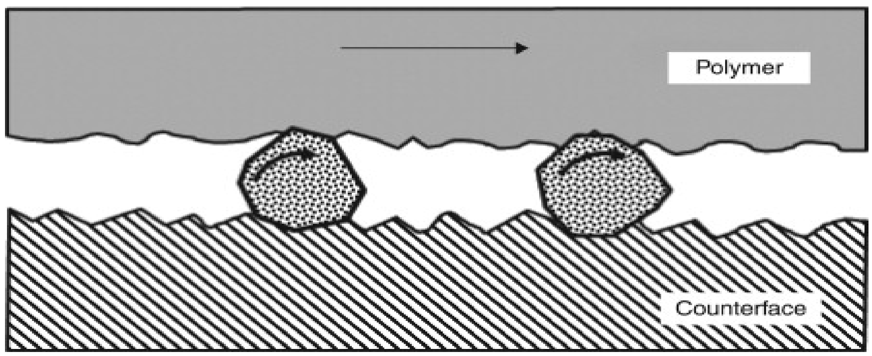


Fig.1.4 Three body abrasion

Fretting wear:

Fretting wear occurs between two contacting surfaces having oscillatory relative motion of small amplitude. This type of damage has grat economical and safety impact on the operation of nuclear reactors,since a large number of their components are subjected to flow-induced vibrations. It is a very destructive phenomenon that occurs between two contacting surfaces when they experience relative movement at minute displacement under load.According to the relative movement of the mating surfaaces,fretting has two modes:(a) gross-slip, where relative movement occurs across the entire contact interface and (b) partial stick,where slip occurs near the edge of contact with no slip (i.e. stick) in the central region .[7]

Erosive wear:

Erosive wear can be defined as degradation of material due to impact of paricles travelling with significant velocity. A tribosystem suffering from erosive wear can be charecterized as an open sysytem.[8]

Erosive wear takes place when hard solid particles impact on a surface(Tilly,1977; Hutchings, 1992; Charles et al.,1997) and materials loss due to erosion E is measured as the ratio of the mass of removed material with repect to the mass of erosive particles.Fig.1.3 [9-10]

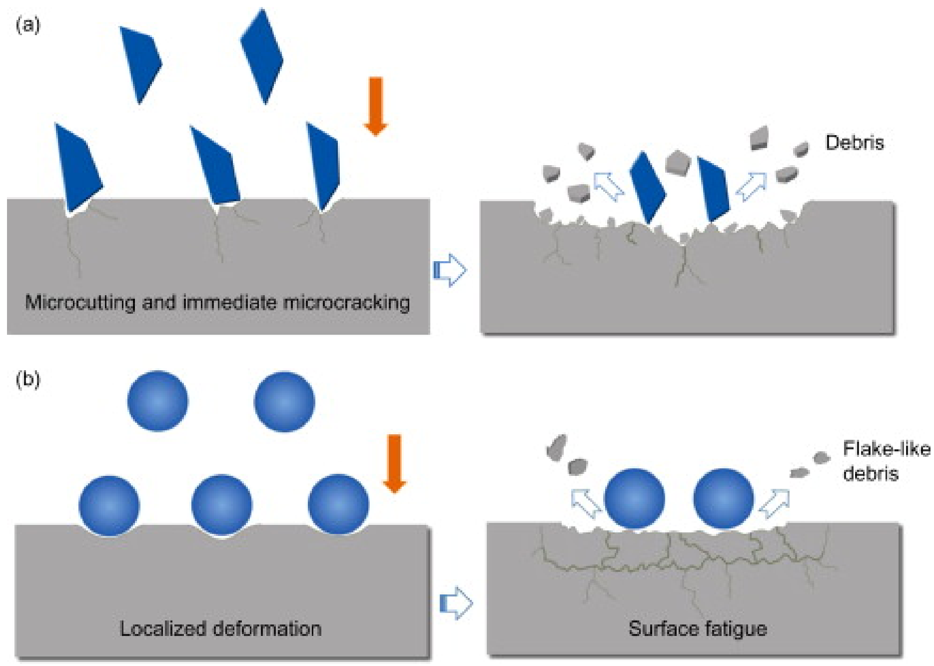


Fig.1.5 Erosivewear

Fatigue wear :

The term ‘contact fatigue ’or ‘surface fatigue ’ commonly used in the literature is technical jargon for surface damage caused by a repeated rolling contact. It refers to the initial damage on a smooth surface and is most often used in the context of rolling bearings [11].

The term “surface fatigue’covers the combination of wear mechanism, operating within a surface layer of several micrometers in thickness, that are caused by tangential shera stress at the material surface as well as by interative impacts .The surface fatigue is charecterized by crack formation along the grain boundaries or cleavage planes starting at the surface and progressing contineously to grater depth by subcritical crack growth. Fig.1.6 [12]

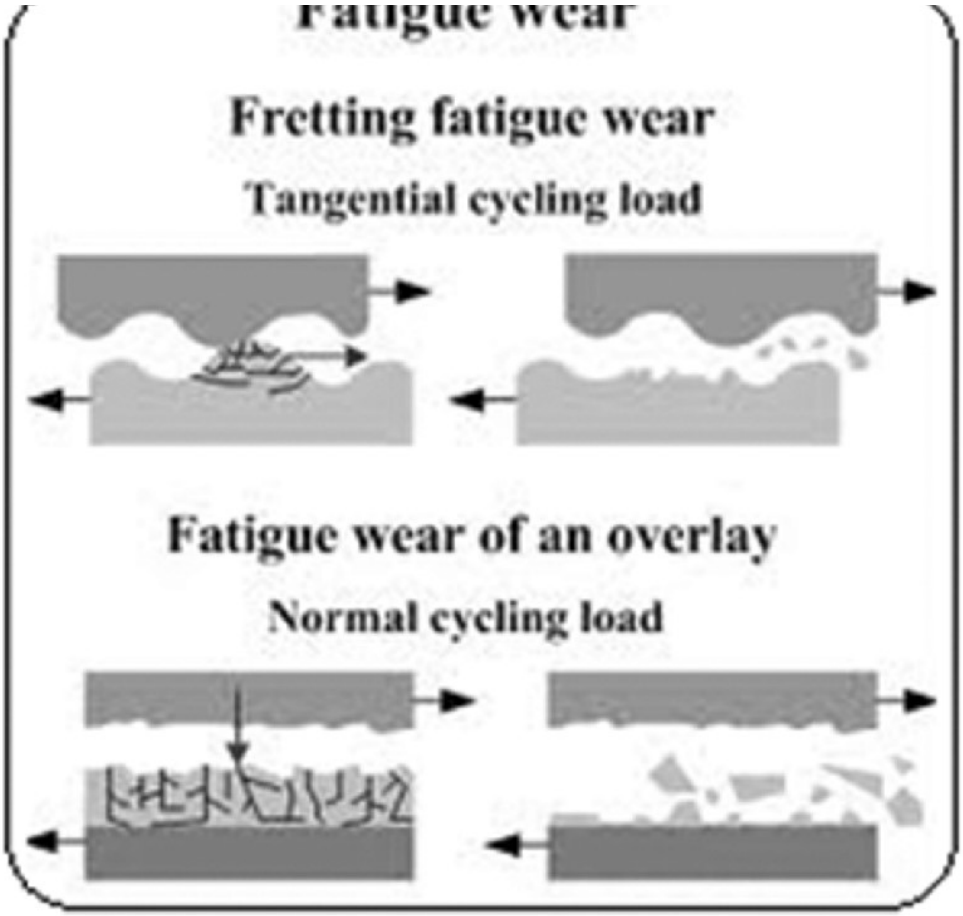


Fig.1.6 Fatiguewear

1.3 Wear testing machine or tribometer

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

1.3.1 Miller testing apparatus (ASTM G-75)

Miller testing apparatus is based on the procedure given under ASTM G-75. The miller number is used to rank the abrasiveness of slurries in terms of wear of standard refrence manual. Slurry Abrasive of material(SAR number) is an index to determine the abrasive response of different material under slurry condition .[13]

1.3.2 Jet impingement tester (ASTM G-73-82)

Inthis experimental procedure ,the solid specimen is contineously eroded by the impact of liquid jet. This test is performed for the evaluation of corrosion behaviour of specimen. In this method, water is sprayed through the nozzle on the solid specimen. It comprises of a pump and and ejector to issue a jet through a nozzle. Jet impingement tester simulates the wear for direct impact of solid particles in equipement such as pumps,bends, tee junction, elbows, contraction etc. This method is not applicable for pending erosion wear or particle impact in bouncy flow.[14]

1.3.3Pin on disk apparatus (ASTM G-99)

This method measures the wear rate,coefficient of friction of material using pin on disk apparatus. This method also helps in determining the coefficient of friction. During tribological test, the pin rotates against a stationary disk under variant load. The amount of wear is determined by measuring appropriate linear dimensions of both specimen before and after the test or by weighing both specimen before and after the test [15].

1.4 Stages of wear

Wear mechanisms generally can be grouped into six generic types:

- Adhesive Mechanisms
- Single & Repeated-cycle deformation mechanisms
- Chemical mechanisms
- Thermal mechanisms

- Tribofilm mechanisms

Two or more type of mechanism can be involved in a real wear situation. Therefore, materials can exhibit transitions in wear behavior as a result of changes in other operational parameters, such as load, velocity, and friction. Under normal mechanical and practical procedures, the wear-rate normally changes through three different stages. In explicit wear tests simulating industrial conditions between metallic surfaces, there are no clear chronological distinction between different wear-stages due to big overlaps and symbiotic relations between various friction mechanisms. Surface engineering and treatments are used to minimize wear and extend the components working life.

1.5 Measurement of wear

The identification of wear mechanisms and surface damages is an important part of any tribotesting procedure and should accompany the measuring of wear and friction values. And the most commonly used technique for the evaluation of wear from material surface is weighing of materials and measurement of change in dimension [19]

For the relatively elementary of two loaded surfaces, one hard the other softer, sliding over one another we might suppose that the loss of linear dimension, say w, in the wearing surface will depend on the applied load P, the imposed sliding speed V, the coefficient of friction m, the hardness H of the softer surface the time they slide together t and the size of the contact measured by some representative length dimension R. Hardness, as a plastic property, is included rather than the elastic modulus since, for ductile metals, wear is generally only achieved after significant plastic flow. It is thus possible to write

$$W = f\,(P,V,m\ H,t,\ R)$$

Experiments have shown that there is no correlation between the coefficient of friction m and wear rate hence can be neglected. On making further simplification the equation of wear rate reduces to

$$W = KPV/R2H$$

Where K is constant whose value varies for type of surfaces.

Some researchers used to measure abrasive wear rate (W) using weight-loss measurements and use the following formula:

$$W = V/\rho D$$

where ρ is the density of the composite, V the weight loss and D is the sliding distance.

CHAPTER 2

LITERATURE REVIEW

J. O. Bird, P. J. Chivers (1993) they studied the measurement of coeffiecient of friction and they found amount of friction existing between two surfaces for high and low friction. They found low value of coefficient of friction indicates that the force required for sliding to occur is less than the force required when the coefficient of friction is high. They studied on three parameters of metal which is oil polished metal surface, glass and rubber turmac at different value of COF 0.1,0.4,1.0 respectively.

M. Roy (2008) they studied on erosive wear and he stated that erosive wear can be defined as degradation of material due to impact of particles travelling with significant velocty and also find a tribosystem is suffering from erosive wear in an open system. In this system counter body of tribosystem were replaced. He also stated that old technique or methodologies have been developed for studying its mechanism for assessing the extent of erosion.

H. Dong (2010)is studied on fretting wear and he found wear occurs between two contacting surface of solid and they experience relative movement at a minute diplacement under load.he find in his experiment on titanium alloys multiple wear occurs such as adhesive, abrasive and oxidative wear simultaneously. And he found titanium alloys has high tendency for adhesion which causes sticking. He says in his experiment titanium alloy have a very strong affinity to oxygen.

A.E. Jimenez, M.D. Burmudez (2011)studies on ductile and brittle material for erosive wear and found that ductile material have maximum erosion rate for an impact angle around 20. Whereas brittle material has very resistance under normal impact at low angle. Ductile material also shows extensive plastic flow of the surface around point of the impact.while brittle material produces propagation of crack due to impact of hard particles which lead to material from the surface of material.

Vicky Vikram Das, Chandi Prasad Mohanti (2011) they studied on tribological studies of aluminum alloy and found wear is dependent on applied load. They saw wear increase at higher sliding speed at higher applied load. They have work done under lubricated condition the specimen shows higher amount of material loss.

Fred k.Gietner, P. Bloch (2012)they studied on abrasive wear and gives the solution of machinary failure in industry and they say abrasive wear occurs when a certain material scratches or gouges a softer surface and found the abrasion is rsponsible for 50% all failures in material.they one example of abrasive wear is that abrasive wear damage of crankshaft journals in reciprocating compressors.Hard dirt particles will break through the lubricant film nd cut or scratch the softer surface.

V.N. Malshev(2014) has studied that coefficient of friction (COF) is measured by experimentally and cannot be findout by calculation.he also stated that $\mu$is always less than 1 is not true.while in most relevant application like slicon or acrylic rubber-coated surfaces have a COF that be substantially greater than 1.it stated that force required to slide an object along the surface is greater than the normal force of the surface on the object.

K. R. Padmavathi, Dr. R. Ramakrishnan (2014) have studied the tribological behaviour of aluminum hybrid metal matrix composite arefound stir casting is suitable for hybrib metal matrix composite. It observed that abrasive wear exhibit better on aluminum reinforce with SiC. They also found hardness of composites increase as the hybrid ratio increase.

R. C. Singh, et. al. (2015) have studied in the investigation of wear bheaviour of aluminum alloy with pure aluminum. The wear rate for Al-10.6%Si-2.4%Cu is not increasing at a high rate up to the load of 1.5kg instead it is constant but beyond this value of load the it is decreasing but the wear rate for pure aluminium is first increasing slowly up to the load of 2kg. then increases sharply with increase of applied load. coefficient of friction for auminium alloy nearly remain constant up to load of 2kg but beyond this it increases due to increased metal to metal contact and for pure aluminium Its value increases up to load of 2kg due to more formation of debris with increase of load but beyond the load of 2kg it has been found to remain approximately constant.

H. Zhang (2016) has studied on coefficient of friction stated that coefficient of friction is a dimensionless number that defines the ratio between frictional force and normal force and he worked on polymer sheet with fixed weight on top and dragged polymer along stainless steel under dry and wet conditions for measurement of friction force by forcemeter .and he found the normal force in this test is equal to the gravity force weight.he used ASTM D1894-14 for this test.

CH. Mohana Rao, K. Mallikarjuna Rao (2016) have studied on abrasive wear behaviour of TiB fabricated aluminum 6061.they do surface friction stir processd of aluminum composite 6061 and found surface was smooth without any defects such as void, crack and improper mixing. They took aluminum alloy 6061 plate of thickness of 6mm and they have cutting tools in rectangular shape with dimension of 100mm, 70mm, 6mm.

Jens Whalstrom, et. al. (2017) they studeid on disk brake contact pairs with respect to wear and airborne particle emission on pin on disk tribomter.and their purpose to research on that topic is that to investigate wear and particle emission of three novel friction material formulation. Result of their study is the coefficient of friction and disc temperature are at the same level for all contact pairs after run in. they found 50% reduction in particle emission in comparison to referncive material by using a WC/CoCr disc coating.

Igor Velkavrh, et. al. (2017) have studied to analyse friction in metal forming process by using pin on disc tribometer. They observed that coefficient of friction was measured on sliding plates which made of same materials having a identical surface roughness. After the test the test sample had a similar microstructure which indicates that the tribological conditions were similar in both cases.

S. Ranganathan, T. S. A. Suryakumari (2017) have studied wear behaviour of aluminum hybrid composite, the Taguchi based L9 orthogonal array was considered to fabricate the hybrid MMCs and the wear test under dry sliding wear conditions.they found the high micro hardness of hybrid MMC is obtained with the composition of 2.5 % of Al2O3 and 5 % of SiC composites.and also observed that wear increases with an increased content of Al2O3 and increase in applied load and sliding distance. The friction force increases with increase in applied force and decrease in sliding distance. And co-efficient of friction increases with decrease in sliding distance and applied load. Al 7075 alloy is an aluminium alloy, with zinc as the primary alloying element. It is a strong alloy compared to many steels, and has good fatigue strength and average machinability, but has less resistance to corrosion than many other Al alloys. Its tribological properties enriched by fabricating the hybrid metal matrix composite with the Al2O3 and SiC particulate reinforcements. Micro hardness test was carried out for nine specimens on Vickers micro hardness tester by applying 500g load. Fig. 1 shows the micro hardness values for nine samples using L9 orthogonal array. Al7075 reinforced with 2.5% Al2O3 and 5% SiC resulted in high micro hardness. Increase in weight percentage of reinforcements resulted high hardness initially and further addition of reinforcements led to poor micro hardness due to improper dispersion of reinforced particles and formation of clusters.

Egemen Avcu (2017) has studied on dry sliding behaviour of aluminum alloy 7075 found in their study dry sliding behaviour of ECAP processed AA7075 aluminium alloy has been investigated via ball-on disc wear tests. The microstructure, the microhardness, the volume loss, the specific wear rate, the worn surface topography and morphology of the homogenized, ECAP processed specimens with 2 and 4 passes were characterized in detail .He observed that the coefficient of friction increased with ECAP and number of ECAP passes despite of the improved hardness. ECAP caused to increases in the volume loss, the mass loss and the specific wear rate with Small spherical grain structure, coarse plate-like and fine precipitates were predominant for the microstructures of homogenized specimen, whereas partly elongated grain structure and finer precipitates became more dominant for the ECAP processed specimens. ECAP process dramatically enhanced the microhardness due to fragmentation of precipitates and grain refinement.

G. B. Galvani, R. O. Ferrriera et. al. (2019) have studied on charecterization and evaluation of coefficient of friction during pin on disc tribotest and compare C10200 Cu, AA 6082-T6 Al and C36000 brass pin under varying load found wear rate of the Al alloy and Cu pins was mild, while the brass pin showed severe wear, due to the preferential α/β interfacial cracking of the brass inside the plastically deformed layer. And formation of Cu patches adhered on the tribosurface of the steel disc acted as a source of instability of the CoF evolution of the Cu-steel system due to the stick-slip.they also found Pin on disc tribotests allowed the comparison between C10200 Cu, AA6082-T6 Al alloy and C36000 leaded α+β brass pins under varying nominal contact pressures. Microscopic characterization showed, for all conditions, the nature of the transfer layer controlled the sliding wear mechanism, the average CoF values and the stability of the CoF evolution.

Srinivasula Reddy, Kaliveeran Vadivuchezhian (2019) have studied the sliding of various ductile materials (Al6082, Al6061) by using pin on disc setup to understand the variation of coefficient of friction over a period of time. And they noted that the formation of oxide and nitride layers are dominant. They tested their experiment using aluminum alloy (Al6061, Al6082) with constant load at speed of 1.5m/s. they are also observed that coefficient of friction have lower value given by the pin on disk experiment. And coeffiecient of friction their first material has greater value as compared to their send material under similar load.

Vidyasri Khadanga et.al. (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.

S. Karthikeyan, A. Prathima et. al. (2020) have studied on analysis of steel ST 75 using pin on disc tribotester and observed that the highest wear faactor is located with 40N with a wear factor of 4.9. while at 10N, 20N, 30 N are 4.0, 4.52, 4.72.also widht of wear is locted higher at 40N is 0.9820 whereas at 10N, 20N, and 30N are 0.6643, 0.7028, and 0.8549mm. And their research method is by the way ST 75 steel wear testing using pin on disc tribotester tool with variation loading condition with speed. The rotation speed adjusted by using an inverter with a rotation speed of 75rpm,and the lubricant were used SAE40 under the load of 10N, 20, and 30N.

P. Krishna kumar, A. Satish kumar (2020) have studied on the investigation of frictional charecterstic of laser textured Al6061 and Al7071under dry sliding condition in pin on disc tribotester. They found that the laser textured pattern developed over the siding surface of Al6061 and Al7075 alloy has reduced its coefficient value. Due to the formation of wear debris over the sliding surface of the pin has shown higher friction coefficient value. Overall circular,square and triangular pattern of Al7075 alloy has shown the averge friction coefficient value of 0.277, 0.311, 0.224 respectively. Whereas the circular, square, triangular pattern of Al6061 alloy has shown average friction coefficient value is 0.460, 0.296, and 0.184 respectively. Because of presence of magnesium and silicon as a major alloying constituent in Al6061 alloy exhibits low friction coefficient. Laser surface texturing produces a very large number of dimples of the circular, square, and triangular pattern on the sliding surface.

Dilkush Shaik, I. Sudhakar et. al. (2020) they had study on the tribological behaviour of friction stir processedAA6061 aluminum alloy they observed that changing the surface morphology of AA6061 by carbide powder (boron), silicon, and tungsten by using stir processing exhbit better wear resistance as compared to base metal. From the SEM analysis, it is clearly observed that abrasion wear is the primary cause for less wear resistance in AA 6061 aluminium alloy while as adhesive wear mechanism is found to be predominant one in all other surface composites resulting in the increase of wear resistance. Thus, it is recommended to use B4C as reinforcing material for surface modification of AA6061 aluminum alloy when compared with other reinforcing materials of WC and SiC.

Gunda Rakesh, Narala suresh (2020) have studied on the tribological studies of EN 31 steel and Ti-6Al-4V alloy material by using pin on disc tribometer. They were performed to determine the lubrication performance of solid lubricant emulsion against EN31 steel and Ti-6Al-4V and evaluated tribological properties of sliding temperature of the lubricated surface by varying the normal load conditions. And also observed that sliding properties have been improved by slected lubricants as compared to dry sliding conditions. They analyse the wear morphology it indicates that the solid lubricant decreases rate of wear and resulted in a relative smooth surface with fewer scars in both EN31 and Ti-6Al-4V alloy.

CHAPTER 3

PROBLEM FORMULATION

3.1 Need of present work

On the basis of literature survey it has been observed that the wear studies were conducted on wide varieties of materials/alloys. It has been observed that theoretical calculations differ from experimental results. In every theory the surfaces which are kept in contact for wear to take place are in horizontal position But in my project we kept in contact for wear kept to take place are in vertical position. Wearing and tearing is an essential factor of engineering and desingning process because it causes change in dimension of material. Now a days aluminum alloy are widely used for aircrafts and construction application. This research work is done in order to provide that particular test result to facilitate engg. to predict tribological behaviour of aluminum alloy and steel parts.

3.2 Problem formulation

In order to solve the present research problem related to application of aluminum alloy 5652 disc, high speed steel and aluminum pin used in engineering work and construction application. The low rotation of speed is 250 rpm is selected with an applied load 10N. for other evaluation rotational speed is 300rpm, 350rpm, 400rpm, 450rpm and 500rpm is selected with the load of 20N, 30N. In the present work, Al5652 alloy sheet, high speed steel and aluminum specimen is taken for investigation on mass loss due to wear.And the mass is caculated on the basis of experimental runs on setup by applying varying load on the lever which is available on the setup.

3.3 Objective of present work

To perform the experiments & investigate the tribological behaviour and wear charecterstics of Al5652 aluminum alloy disc, aluminum pin by using pin on disc setup at different load. In this connection the following procedure were aimed to be carried out.

- To investigate the tribological wear behaviour and wear charecterstics of Al5652 alloy disc, aluminumspecimen by varying different RPM on the alloy sheet (250rpm, 300rpm, 400rpm, & 500rpm)
- To select three different materials for the desired test according to availability.
- To determine the wear rate at different applied loads.
- To perform statistical analysis and formulate the mathematical model of the results obtained.
- To study the wear characteristics of the selected materials at vertical orientation of the specimen.

3.4 Mathematical model for formulation

Tribology deals with friction, wear and lubrication between the two surfaces in relative motion. A Tribometer is an instrument that measures tribological quantities, such as coefficient of friction, friction force, and wear rate. The machines due to wear lose their durability and reliability. Wear can be defined as the phenomenon of removing the material from the surface due to interaction with a mating surface . Wear might have different patterns corresponding to various wear mechanisms. A surface can be subjected to more than one wear mechanism simultaneously [20].

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

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

Where, [W1-W2]/ρ =Volume of material removed

2πRNT = 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 .

CHAPTER 4

METHODOLOGY

This section represents the methodology of present work, which include the details of selection material, material properties, experimental setup, and experimental procedure.

To carry out the whole test, we used Al5652 alloy disc of weight 194.5gm. and also used tool holder where we hold the specimen of aluminum at different load.

The whole was carried out at fix time of 1 minute at different RPM 250rpm, 300rpm, 400rpm, and 500rpm. And also at 10N, 20N, 30N, In which we measure the mass of workpiece before and after.

The reading of mass wear out has taken upto 3 digit after decimal by the help of load cell.

4.1 Selection of material

During my research & observation it was found that tribological behaviour and wear charecterstics aluminum alloy has been already carried out on several aluminum alloy .thatswhy I chose Al5652 alloy for my testing.

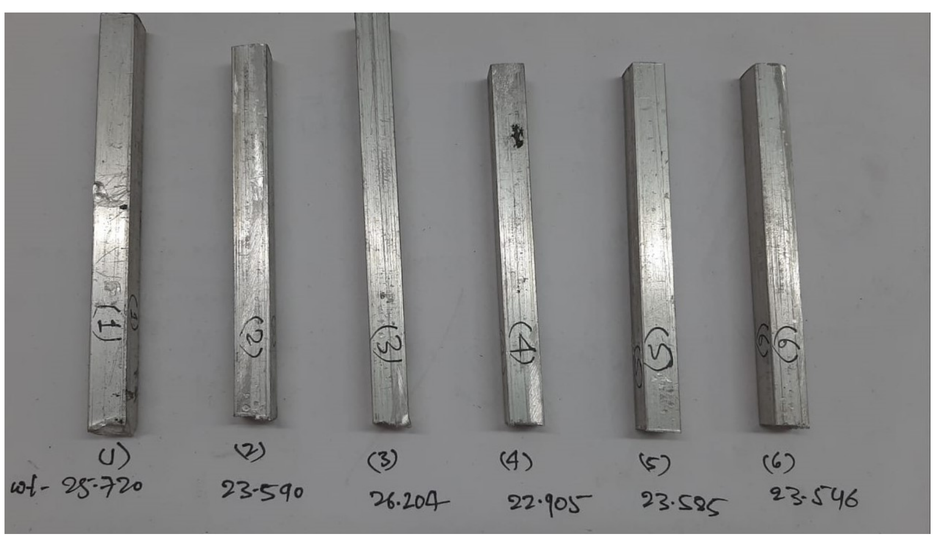


Fig.1.7(a) Test specimen of aluminum before experimen

Fig.1.7(b) Test specimen of aluminum after test

4.1.3 **Description of the part of wear test rig design**

4.1.3.1 Regulator or controller

Regulator of a direct current motor is used to regulate the speed of motor [Fig. 1.7]. it can directly be control by the special arrangement of direct current motor.

Fig.1.8 controller

4.1.3.2 D.C Motor

A D.C motor consist of a stator, an armaure,a rotor and commulator with brushes. Opposite polarity between the two magnetic fields inside the motor cause it to turn DC motors are the simplest type of motor and are used in household appliance such as electric razors and electric windows in cars.

A DC motor [Fig. 1.8] is equipped with magnetts either permanent magnet or electro magnetic winding that produce a magnetic field. when current passes through the armature, also kown as the coil or wire, placed between the north and south poes of the magnet, the field generated by the armature interacts with the field from the magnet and applies torque. In DC motor, the magnet forms the stator, armature is placed on the rotor and a commutatr conects the stationary power source to the armature through the use of brush or conductive rods. Furthermore, DC motor perate at fixed speed for fixed voltage and there is no slip.

Fig. 1.9 Pin on disc setup

4.1.3.3 Aluminum alloy sheet

5652 aluminum is a 5000-series aluminum alloy: the main alloying addition is magnesium, and it is formulated for primary forming into wrought products. 5652 is the Aluminum Association (AA) designation for this material. In European standards, it will be given as EN AW-5652. A95652 is the UNS number.

The properties of 5652 aluminum include eight common variations. This page shows summary ranges across all of them. For more specific values, follow the links immediately below. The graph bars on the material properties cards further below compare 5652 aluminum to: 5000-series alloys (top), all aluminum alloys (middle), and the entire database (bottom). A full bar means this is the highest value in the relevant set. A half-full bar means it's 50% of the highest, and so on. 5000 series aluminum alloys have very good corrosion resistance, weld ability, workability, strength, and toughness. Aluminum 5652 alloy is a wrought alloy type.

Table 1: Chemical composition of aluminum5652 alloy sheet

Element	**Content %**
Aluminum, Al	97.2
Magnesium , Mg	2.5
Chromium ,Cr	0.25

Table 2: Physical&Mechanical properties of disc

Properties	**Value**
Density	2.67 g/cm^3
Melting point	607-649 ℃
Tensile strength	290 MPa
Yield strength	255 MPa
Hardness, brinell	77
Hardness, knoop	100
Hardness, vickers	87

Fig.2.0 (a) Aluminum alloy sheet before testing

Fig.2.1 (b) Aluminum5652 alloy sheet after testing

Fig. 2.1 (c) Alumunium5652 alloy disc after test

4.1.3.4 Weighing machine

Weighing machine is used for severals application like industrial, research, chemical, pharmaceutical, electronics, precious metals, jewellery (commonly sold as 'carat scale'), diamond scale, jewellery scale and in educational applications. Before the test the weight of test specimen and disc was taken accurately using electronic balance with an accuracy of 0.001g. the maximum weight capacity of th electronic balance was 320g. weighing machine is to be used in this experiment is show below **.**

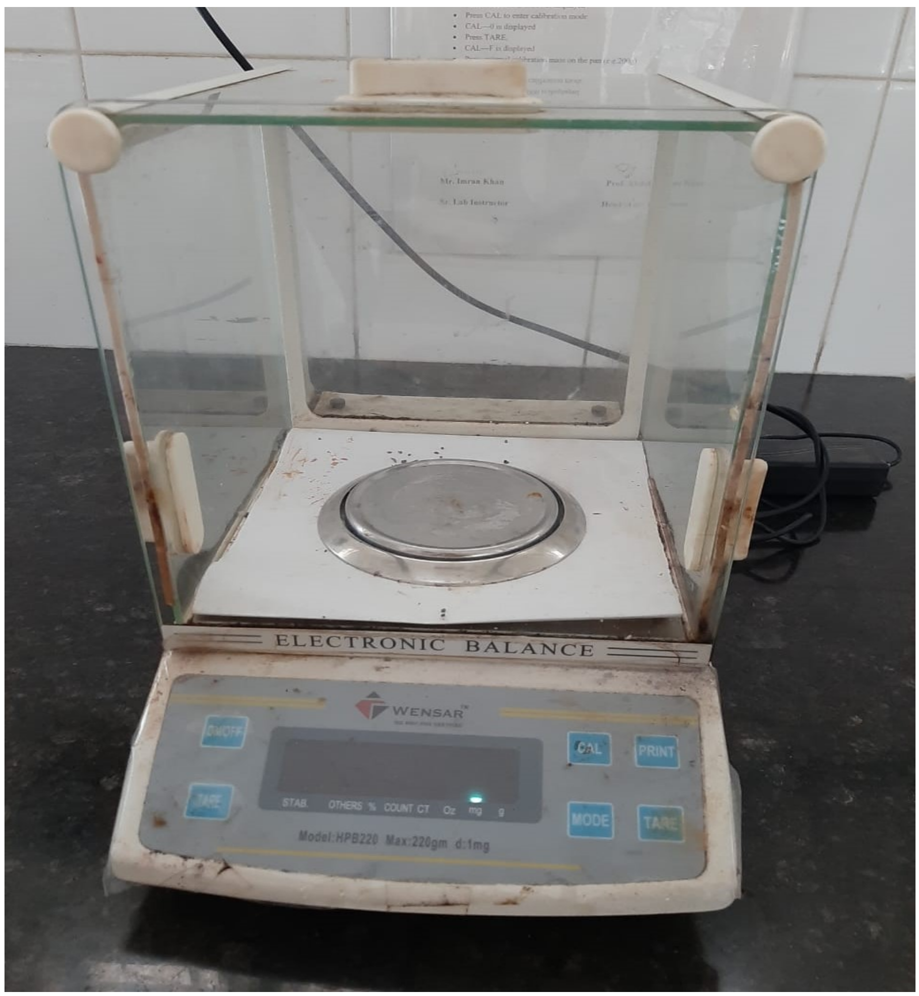


Fig.2.2 Weighing machine

4.2 Wear charecterization

The following method was adopted for wear charect.

- Selection of applied load and the position of the specimen
- Speed of alloy disc
-

4.2.1 Selection of applied load and position of the speimen

The following loads were selected for present objective

(1)10N

(2) 20N

(3) 30N

For each load position of the specimen were kept verically on work sheet.

4.2.2 Speed of rotating alloy wheel

The speed of rotating disc varies from 250rpm, 300rpm, 400rpm, 500rpm, . For a particular loading conditions.

CHAPTER 5

EXPERIMENTAL ANALYSIS

The whole analysis is mainly consider three important factor which are as follows

- ✓ Applied load conditions (N) 10N, 20N, and 30N
- ✓ Speed of rotating wheel 250rpm, 300rpm, 400rpm, 500rpm
- ✓ Determination of mass loss on both specimen and disc

The complete analysis is comes under these factor. First we consider a constant orientatiom angle and change the speed of wheel under varying load conditions

5.1 Test procedure

Before the test weight of the specimen is taken accurately using a electronic balance with an accuracy of 0.001g. the maximum weight capacity of the electronics balance was 320g. after a travel time of 1,2 minute against the disc. The sample was taken out carefully so that the debris were from the valley of the disc and specimen and exact wear of material can be measured. Once again weight was taken carefully using the above balance and the doffrent in weight was noted. This was taken carefully using above balance. This was continued for five times with different specimen at same position. After that next secimen was taken for next condition. The test were conducted for four different speed of grinding wheel and at different loading conditions 10N, 20N, 30N. Thus a total of 15 reading is taken out for one particular speed. This is continued for speed of 250rpm, 300rpm, 400rpm, 500rpm respectively.

Wear loss is estimated by calculating the wear loss of mass after each test for both specimen and disc. The weight loss due to wear is calculated by taking the diffrence between initial weight and finl weight.

5.1.1 Loading condition at 10N

When we simply consider 10N loading condition and consider 6 specimen of aluminum, and 1 rotating aluminum5652 disc with four different speed of rotating wheel then approximately 24 reading are taken. Following possibilities of mass loss is arises

Table 3:Loading condition at 10N

S.NO.	SPECIMEN	SPEED OF WHEEL(RPM)	MASS LOSS (gm)	MEAN OF THE MASS LOSS(gm)
1	1	250	0.032	0.064
2	2	250	0.049	
3	3	250	0.057	
4	4	250	0.076	
5	5	250	0.087	
6	6	250	0.087	
7	1	300	0.223	0.162
8	2	300	0.132	
9	3	300	0.128	
10	4	300	0.125	
11	5	300	0.212	
12	6	300	0.152	
13	1	400	0.221	0.217
14	2	400	0.241	
15	3	400	0.146	
16	4	400	0.243	
17	5	400	0.227	
18	6	400	0.224	
19	1	500	0.265	0.363
20	2	500	0.331	
21	3	500	0.271	
22	4	500	0.379	
23	5	500	0.477	
24	6	500	0.456	

5.1.2 Second loading condition at 20N

When we simply consider 20N loading condition and consider 6 specimen of aluminum, and 1 rotating aluminum5652 disc with four different speed of rotating wheel then approximately 24 reading are taken.

Table: 4 Second loading condition at 20N

S.NO.	SPECIMEN	SPEED WHEEL(RPM)	MASS LOSS (gm)	MEAN LOSS OF MASS (gm)
1	1	250	0.0695	0.078
2	2	250	0.0745	
3	3	250	0.0842	
4	4	250	0.0778	
5	5	250	0.0872	
6	6	250	0.0778	
7	1	300	0.1689	0.182
8	2	300	0.1987	
9	3	300	0.1764	
10	4	300	0.1984	
11	5	300	0.1789	
12	6	300	0.1758	
13	1	400	0.2795	0.255
14	2	400	0.2687	
15	3	400	0.2689	
16	4	400	0.2568	
17	5	400	0.2228	
18	6	400	0.2358	
19	1	500	0.3789	0.370
20	2	500	0.3398	
21	3	500	0.3756	
22	4	500	0.3468	
23	5	500	0.3894	
24	6	500	0.3944	

5.1.3 Third loading condition at 30N

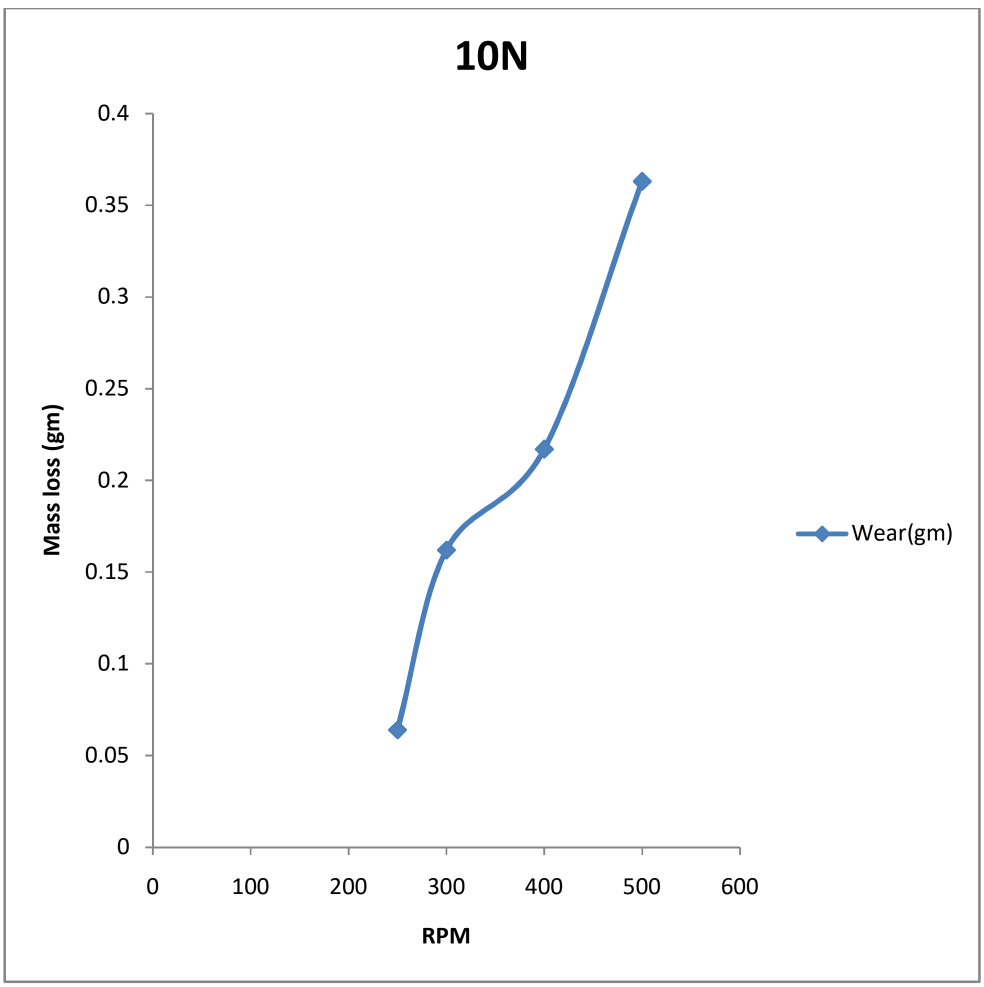
Table:5 Third loading condition at 30N

S.NO.	SPECIMEN	SPEED WHEEL (RPM)	MASS LOSS (gm)	MEAN OF THE MASS (gm)
1	1	250	0.079	0.077
2	2	250	0.124	
3	3	250	0.089	
4	4	250	0.083	
5	5	250	0.091	
6	6	250	0.091	
7	1	300	0.1978	0.194
8	2	300	0.2032	
9	3	300	0.1993	
10	4	300	0.1937	
11	5	300	0.1863	
12	6	300	0.1894	
13	1	400	0.2783	0.255
14	2	400	0.2369	
15	3	400	0.2459	
16	4	400	0.2456	
17	5	400	0.2563	
18	6	400	0.2687	
19	1	500	0.3782	0.359
20	2	500	0.3753	
21	3	500	0.3453	
22	4	500	0.3684	
23	5	500	0.3636	
24	6	500	0.3265	

5.1.4 Graphical representation of wear at 10N

Table 6: RPM Vs WEAR

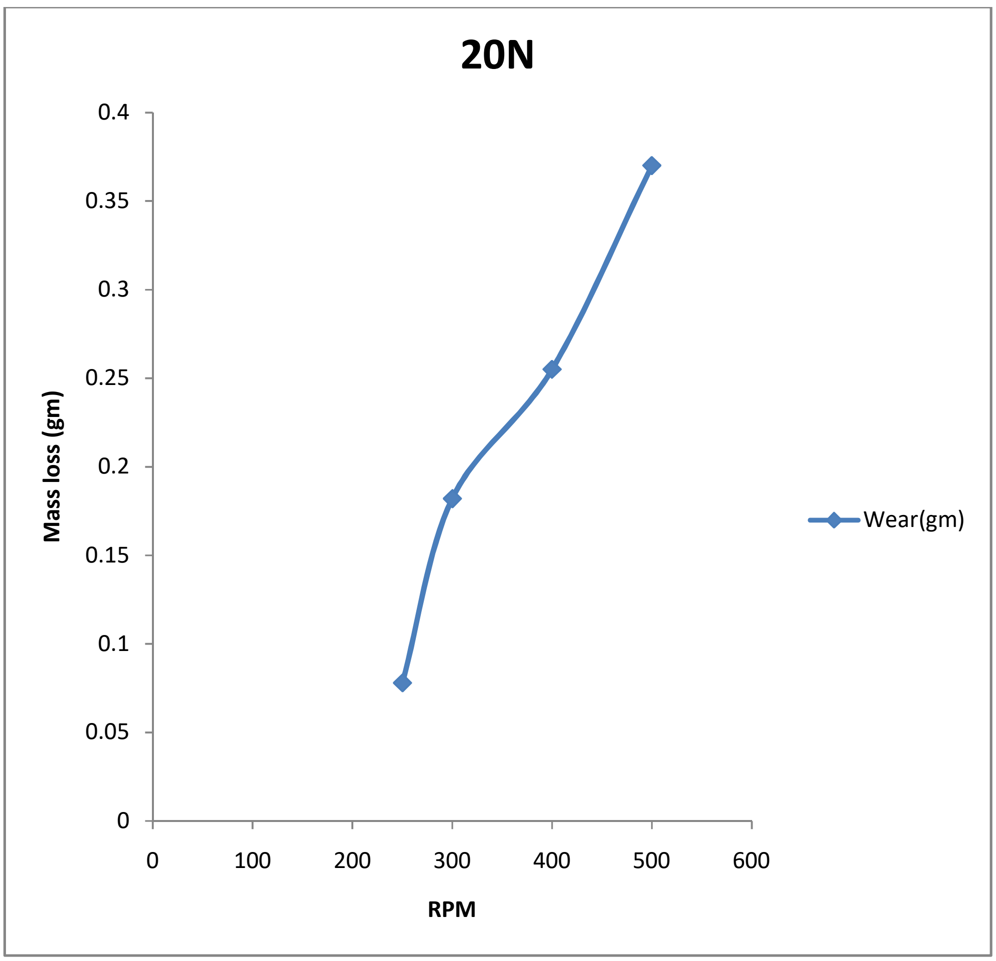
RPM	**WEAR(gm)**
250	0.64
300	0.162
400	0.217
500	0.363



5.1.5 Graphical representation of wear at 20N

Table 7: RPM Vs WEAR

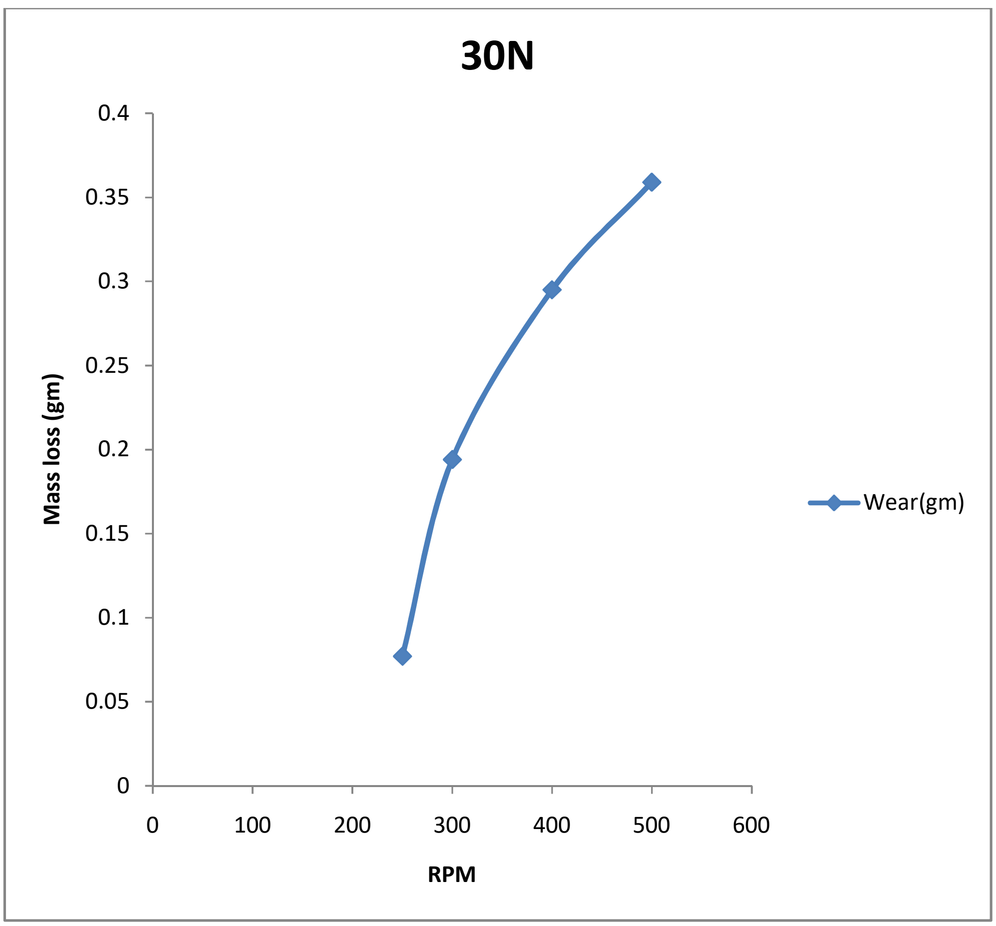
RPM	**WEAR(gm)**
250	0.078
300	0.182
400	0.255
500	0.370



5.1.6 Graphical representation of wear at 30N

Table 8: RPM Vs WEAR

RPM	**WEAR(gm)**
250	0.077
300	0.194
400	0.295
500	0.359



CHAPTER 6
RESULTS AND DISCUSSION

6.1 Results and Discussion

The result of wear rate have been showed as a function of applied load and angular speed. In the present work six different aluminum speciemn and aluminium5652 alloy disc analyst of investigation of mass loss due to friction on their surfaces.

Experiment were conducted for each specimen with loading condition of 10N, 20N, & 30N at the speed of 250rpm, 300rpm, 400rpm, & 500rpm and time was taken 1 minute for analysis.

The result of the six specimen & one alloy disc which is used as a work piece on this present work are represented in the tabulated and graphical form in the order of investigation the variation in the wear with respect to RPM and load. For eaach specimen three reading were calculated and total 24 reading were also calculated for each specimen at a different different rpm and loading condition.

The graphical plots are obtained on the basis of data taken from the experimental work. The plots presneted in this section includes graph of wear vs rpm and wear vs load. The sheet was programmed with formulas to calculate mass loss with their mean value. Graph was plotted using microsoft word.

6.1.1 Effect of applied load on alloy at a constant angular speed

Table 9:Load Vs Wear at 250 rpm

LOAD(N)	WEAR(gm)
10	0.064
20	0.078
30	0.077

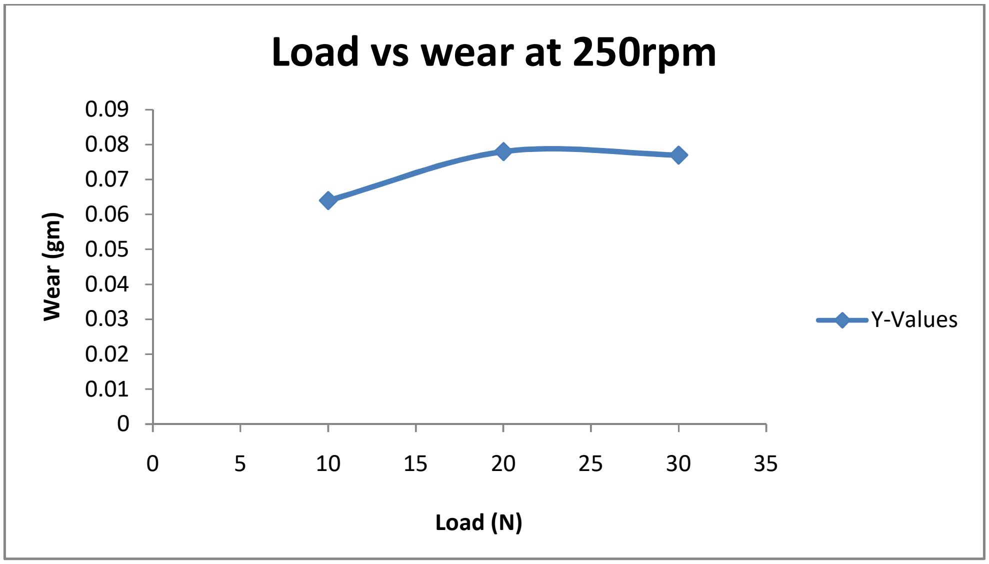


Table10:Load vs wear at 300rpm

Load(N)	**Wear (gm)**
10	0.162
20	0.182
30	0.194

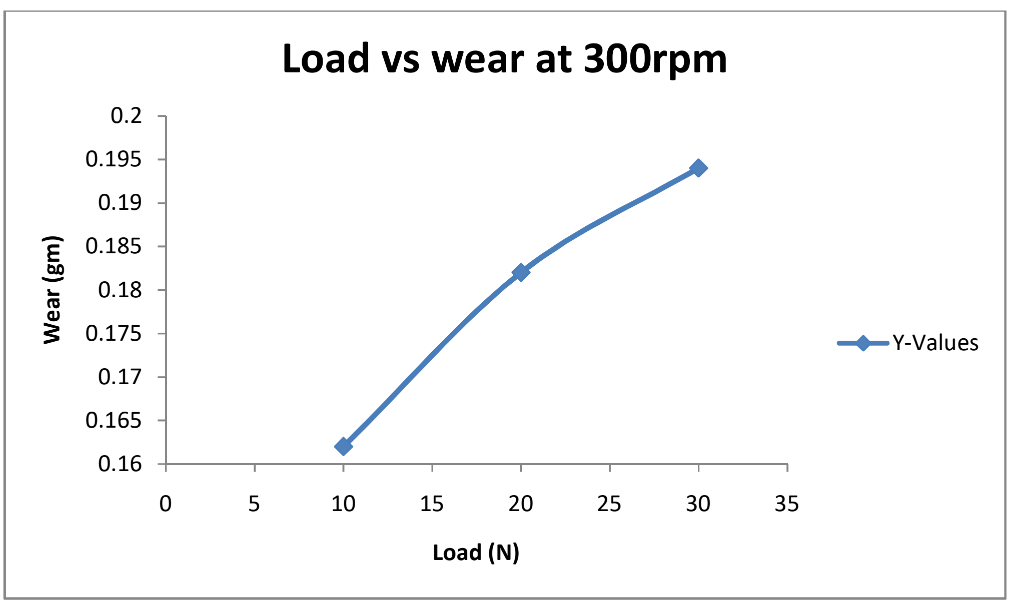
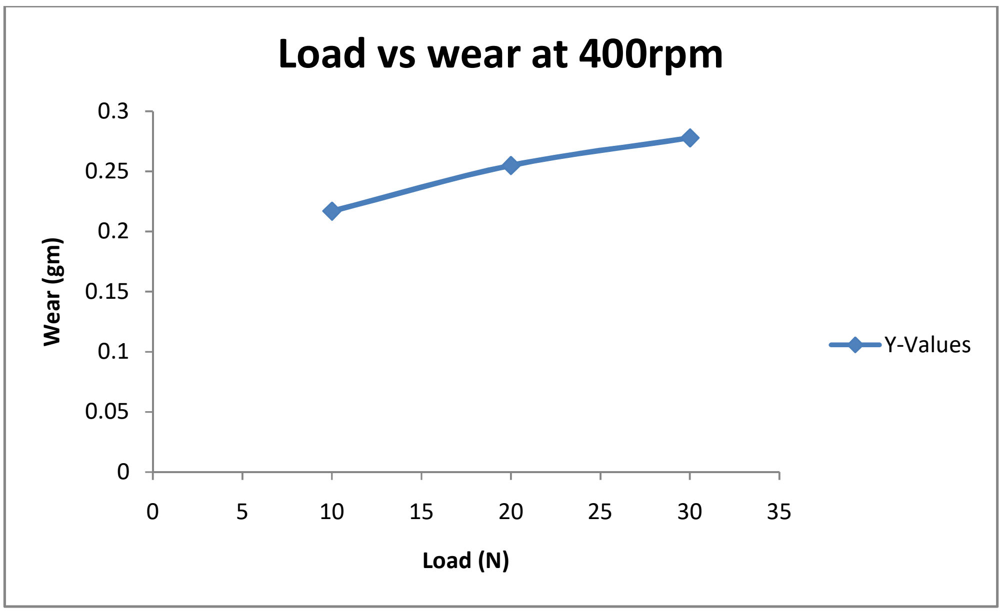


Table 11: Load vs wear at 400 rpm

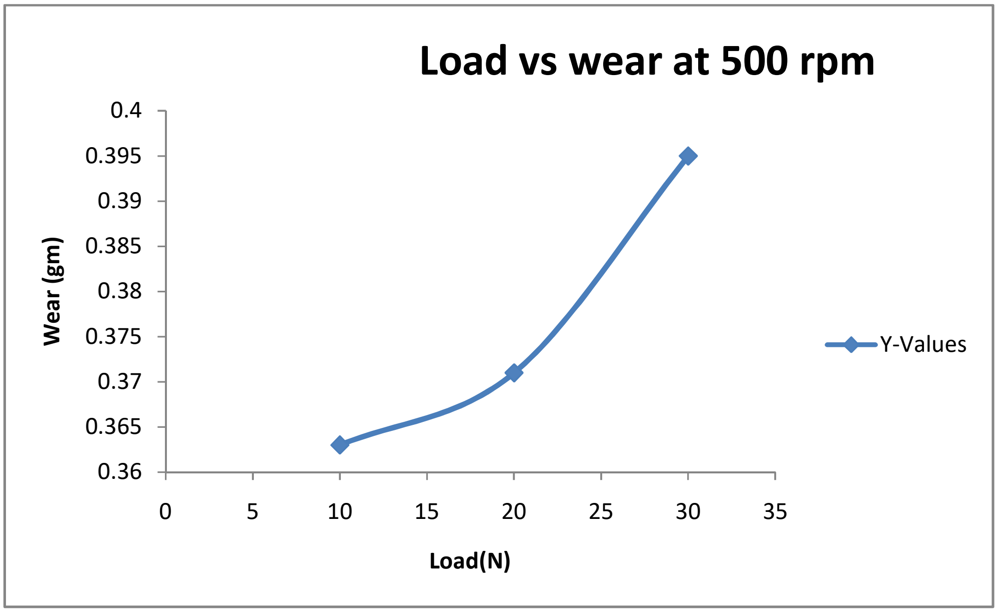
Load (N)	Wear (gm)
10	0.217
20	0.255
30	0.278



Graph 12: Load vs wear at 500 rpm

Table 12:Load vs wear at 500 rpm

Load(N)	Wear(gm)
10	0.363
20	0.370
30	0.395



6.2 DISCUSSION

The basic and important finding if the investigation have been listed out.

6.2.1 RPM Vs WEAR

The average mass loss shows the following main charecterstics

- There is a linear relationship between amount of mass loss due to wear and rotational speeed of aluminum alloy disc.
- The mass loss in first loading condition ih lower as compred to last rotational speed of disc.
- The wear rate is higher at higher speed as compared to lower speed

6.2.2 LOAD Vs WEAR

The investigation shows as follows

- The wear increases as the applied load increases
- As compared to 10N wear is more at 20N,30N
- The graph shows that at 500rpm and at 30N loading, wear rate is maximum

6.3 CONCLUSION

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

- Investigation of wear charecterstics of aluminum 5652 alloy disc and aluminum speciemn is done by using self made apparatus of pin on disc at workshop level rather than highly paid laborities.
- Mean wear of aluminum specimen increases with increase in load and rpm.
- According to random analysis it has been observed that loading condition for selected specimen, rotational speed of 250 rpm and time of 1 minute because there is less wear rate.
- Wear is directly proportional to the applied load and speed .
- Maximum wear occur at maximum loading condition of 30N.
- Maximum wear occur at maximum speed of 500rpm.
- Minimum wear occur at 10N of 250rpm
- The wear increase in between 20N,30N as compare to 10N.
- Similar pattern occurs when rpm increase from 250rpm to 300rpm and 400rpm to 500rpm.

CHAPTER 7

LIMITATION AND FUTURE SCOPE

7.1 Scope for further work

- The present work can be extended by using newly upgraded technology for measurement of wear by pin on disc and materials like aluminum alloy 7^{th} series.
- The experimental work can be extended by increasing the rotational speed of wheel at 500rpm to 1500rpm.
- Low range of rotational speed condition also analysed for same material..
- The experimental work can be extended by varying load condition.
- The experimental setup can be upgraded by another techinque which is better for find out result.
- The setup can also be moodified for automatic cutoff after a cretain range of wear.
- SEM of the specimen can be performed for investigation of micro structural changes after wear.

7.2 Limitations

- Can’t test for higher rpm because of machine efficieny
- Only one test speciemen material is used
- This study was only focused on one infill pattern and percentage.

CHAPTER 8

REFERENCES

1. Dr. Mohd Shadab Khan,() Effect of Orientation and Applied Load on Abrasive Wear Property of a1 6061 Brass 6040 and Mild Steel.
2. I. Srinivasula Reddy, Kaliveeran Vadivuchezhian,(2019) Sliding of various ductile materials (Al 6061, Al 6082) using pin on disc setup.
3. Basavaraj, E, Investigation on mechanical, tribological and morphological behaviours of polymer composites, Department of Polymer Science, University of Mysore,2012. Available at:http://hdl.handle.net/10603/10802 (Accessed : 8/8/2021)
4. Niklas Axen Uppsala University Sture Hogmark Uppsala University Staffan Jacobson Uppsala University Chapter13, Friction And Wear Measurement Techniques.
5. Maria Cristina Tanzi, ... Gabriele Candiani, in Foundations of Biomaterials Engineering, 2019
6. Fred K. Geitner, Heinz P. Bloch, in Machinery Failure Analysis and Troubleshooting (Fourth Edition), 2012.
7. H. Dong, in Surface Engineering of Light Alloys, 2010
8. M. Roy, in Developments in High Temperature Corrosion and Protection of Materials, 2008
9. A.-E. Jiménez, M.-D. Bermúdez, in Tribology for Engineers, 2011
10. Hui Zhang, ... Zhong Zhang, in Multifunctionality of Polymer Composites, 2015
11. Rainer Telle, in Handbook of Ceramics Grinding and Polishing, 2015
12. Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number)
13. Standard Test Method for Liquid Impingement Erosion Using Rotating Apparatus
14. Standard Test Method for Wear Testing with a Pin-on-Disk Apparatus
15. J O Bird BSc, CEng, MIEE, CMath, FIMA, FCollP, MIEIE, P J Chivers BSc, PhD, in Newnes Engineering and Physical Science Pocket Book, 1993
16. O.oyelao,cinta Lorenzo, Tribological aspects in friction stir welding and processing,2017

17. V.N. Malyshev, in Advances in Friction-Stir Welding and Processing, 2014
18. Surface characterization techniques for polyurethane biomaterials,H Zhang, in Advances in Polyurethane Biomaterials, 2016
19. Niklas Axen Uppsala University Sture Hogmark Uppsala University Staffan Jacobson Uppsala University Chapter13, Friction And Wear Measurement Techniques.
20. Gunda Rakesh Kumar,Narala Suresh Kumar, Tribological studies of EN31 steel amd Ti-6Al-4V alloy materials using pin on disc 2020
21. Dilkush Shaika, I. Sudhakar,Tribological behavior of friction stir processed AA6061 aluminium alloy 2020
22. R.O. Ferrreira, G.B. Galvani,Characterization and evolution of the coefficient of friction during pin on disc tribotest: Comparison between C10200 Cu, AA6082-T6 Al and C36000 brass pins under varying normal loads 2019
23. Jens Wahlströma,, Yezhe Lyua,A pin-on-disc tribometer study of disc brake contact pairs with respect to wear and airborne particle emissions 2017
24. Vidyasri Khadanga,Tribological behavior of different disc materials by using pin on disc apparatus 2019
25. Roop Laal Rana, R.C Singh, Investigation of wear behavior of aluminum alloy comparison with pure aluminum. 2015
26. Vicky Vikram Das, Chandi Prasad Mohanty,Tribological studies on aluminum alloy 2011
27. S. Madhava Reddy, A.Chennakesava Reddy,Sliding wear charecterstics of Al-Si-Mg-Fe alloys 2010
28. S.Karthikeyan, A. Prathima, Analysis of steel ST-75 using tribotester pin on disc apparatus 2020
29. K.R.Padmavathia , Dr. R.Ramakrishnanb,Tribological behviour of aluminum hybrid metal matrix composite 2014