ABRASIVE WEAR BEHAVIOR OF ORGANOPOLYSILOXANE

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By

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LUCKNOW

CERTIFICATE

This is to certify that **NIDA KAFIL (Enrollment No 1800104052)** has carried out the research work presented in this thesis entitled **"ABRASIVE WEAR BEHAVIOR OF ORGANOPOLYSILOXANE"** for the award of **Master of Technology** from Integral University, Lucknow under my supervision. The project/thesis embodies results of original work, and studies are carried out by the student herself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

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ABSTRACT

Wear is very important phenomena which play a vital role while designing any component. It directly affects the life of the component. Abrasive wear phenomena are simply caused by the passage of relatively hard particles or asperities over a surface. Abrasive wear simply includes division of two surface parts by abrasion of other mating surface that is situated between the friction areas. A systematic study of abrasive wear of Silicon has been carried out using a two body pin-on-disc wear machine. The objective of this study is to evaluate the abrasive wear of Organopolysiloxane by grinding it at different load at different rpm. In this thesis a study of abrasive wear of Organopolysiloxane at different speed were given to analyze the possibility of wear. A review of abrasive wear behavior of Organopolysiloxane using different wear rate speed has been discussed in this thesis. Mainly focus on the varying wear condition during varying rpm. As we all know that wear is very important parameter which directly affects the life of a component. The goal of this study was to evaluate abrasive wear only.

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ABBREVIATIONS

RPM	**Revolutions per minute**
N	**Newton**

CHAPTER-1

INTRODUCTION

1.1 Introduction

Organosilicon compounds are organometallic compounds containing carbon–silicon bonds. Organosilicon chemistry is the corresponding science of their preparation and properties. Most organosilicon compounds are similar to the ordinary organic compounds, being colourless, flammable, hydrophobic, and stable to air. Silicon carbide is an inorganic compound.

The organopolysiloxane composition proposed is a blend of a conventional diorganopolysiloxane or a dimethylpolysiloxane oil and a limited amount of an (etherified) perfluoroalkyl group-containing organopolysiloxane such as those represented by the group of 1 to 14 carbon atoms or an etherified perfluoroalkyl group of 2 to 14 carbon atoms having at least one oxygen atom between two carbon atoms forming an ether linkage, R is a hydrogen atom or a monovalent hydrocarbon group having 1 to 10 carbon atoms, Y is a divalent organic group having 2 to 5 carbon atoms, the subscripts a and b are, each independently from the other, zero or a positive integer and the subscripts c and d are, each independently from the other, zero, 1, 2 or 3 with the proviso that at least one of the subscripts a, c and d is not zero. By virtue of the admixture of this unique adjuvant, the silicone oil composition can be imparted with greatly increased spreadability even on the surface of a fluorocarbon resin film although the surface tension of the oil is not remarkably decreased thereby.

An organopolysiloxane composition or, more particularly, to an organopolysiloxane composition comprising a fluorocarbon group-containing organopolysiloxane having a remarkably low surface energy and exhibiting excellent wettability and lubricity against various materials.

As is well known, liquid organopolysiloxanes or so-called silicone oils have excellent heat and cold resistance, electric properties, water resistance and chemical resistance so that they are useful in a wide field of applications. One of the most unique properties of silicone oils is their very low surface tension as compared with other liquids including water and various kinds of natural and synthetic oils so that silicone oils can easily spread over the surface of a variety of materials. This unique property of silicone oils is utilized in their applications as surface-release agents, antifoam agents and additives in cosmetic and toiletry compositions.

Certain fluorocarbon polymers such as polytetrafluoroethylene, however, have a still lower surface energy than conventional silicone oils so that the surface of such a resin cannot be coated with a silicone oil with full evenness or exhibits repellency against silicone oils. This means, for example, that silicone oils are not always suitable as a release agent on the surface of an article made from a fluorocarbon resin.

In order to solve the above mentioned problem, proposals have been made heretofore according to which a silicone oil is admixed with a fluorinated hydrocarbon compound or a fluorine-containing surface active agent. This method, however, is not quite satisfactory because of the low compatibility of these fluorine-containing compounds in general with silicone oils resulting in eventual phase separation of the blend not to sustainedly exhibit the desired effects with uniformity.

the inventive organopolysiloxane composition is a uniform blend of two types of distinguishable organopolysiloxanes (a) and (b) defined above in a specified proportion. The first organopolysiloxane, i.e. component (a), is a diorganopolysiloxane having a linear molecular structure as represented by the general formula (I). In the formula, R is a hydrogen atom or a monovalent hydrocarbon group having 1 to 10 carbon atoms exemplified by alkyl groups such as methyl, ethyl, propyl and butyl groups, cycloalkyl groups such as cyclohexyl group, alkenyl groups such as vinyl and allyl groups, aryl groups such as phenyl and tolyl groups and aralkyl groups such as benzyl and 2-phenylethyl groups or, preferably, a methyl group. The hydrocarbon group denoted by R can optionally be substituted by certain reactive functional groups such as amino, (2-aminoethyl) amino, epoxy, carboxyl, methacryloxy and mercapto groups as well as by conventional substituent atoms or groups for a part or all of the hydrogen atoms. It should be noted that two or more hydrogen atoms are never bonded to one and the same silicon atom. R in the formula can be the same as R defined above or can be a hydroxy group. The subscript n, which is a positive integer, gives the degree of polymerization or is a determinant of the viscosity of the organopolysiloxane which should be 100,000 centistokes or lower or, preferably in the range from 50 to 10,000 centistokes at 25° C. depending on the particular application of the inventive composition. When the viscosity of the first organopolysiloxane as the component (a) is too high, the miscibility thereof with the second organopolysiloxane as the component (b) would be decreased so as to cause eventual phase separation by standing the composition as a blend or the spreadability of the composition over the surface of certain substrates may be decreased. Though dependent on the particular application of the composition, it is desirable that the organopolysiloxane as the component (a) is as free as possible from low molecular species having a molecular weight of, for example, 5000 or smaller. In particular, the content of cyclic organopolysiloxanes having a molecular weight smaller than 3000 is desirably 500 ppm or lower.

The second organopolysiloxane as the component (b) to be blended with the first organopolysiloxane as the component (a) to exhibit an effect as a spreadability-improver of the composition is selected from four classes of differently defined organopolysiloxanes (b1) to (b4) having at least one perfluoroalkyl group or etherified perfluoroalkyl group bonded to a silicon atom through a divalent group Y as described above. These four classes of organopolysiloxanes can be used either singly or as a combination of two kinds or more of different classes according to need.

1.2 Production of Organopolysiloxane

The method of making an organopolysiloxane resin which comprises reacting an organesiloxane polymer, having an average of from 1 to 2 hydrocarbon radicals, attached directly to silicon atoms, per atom of silicon, which organosiloxane polymer is initially in liquid state, with an aluminum alkoxide at temperatures between room temperature and 300 C., the aluminum alkoxide being employed in amount between 0.01 per cent of the weight of the organopolysiloxane and a maximum proportion which is varied inversely with the temperature in accordance with values of 5 per cent of the aluminum alkoxide at 300 C. and 20 per cent a

1.3 Properties of Organopolysiloxane

Organopolysiloxane Silicone polymers or polydialkylsiloxanes are an important class of inorganic polymers that find many industrial uses. They are known for their outstanding temperature and oxidative stability, excellent low temperature flexibility, and high resistance to weathering and many chemicals. These polymers also have low surface tension and are capable of wetting most surfaces.

The name **silicone** usually refers to organosilicon polymers with the general structure $-[Si(R_2)-O]-$ where R = $-CH_3$ is called poly(dimethyl siloxane) which is often abbreviated as PDMS:

The methyl groups along the chain can be substituted by many other groups (e.g., ethyl, phenyl, vinyl, etc.) which allows for tailoring the chemical, mechanical and thermophysical properties for a wide variety of applications. The terminal silanol end groups render PDMS susceptible to condensation under both mild acid and base conditions. These resins are either intermediates for room temperature vulcanizeable silicones (RTV) or are converted to many silicone products.

Silicone polymers possess an inorganic -(Si-O)- backbone similar to silicates which are associated with high surface energy. The Si-O bonds are strongly polarized and without side groups, should lead to strong intermolecular interactions. However, the nonpolar methyl groups shield the polar chain backbone. Or in other words, when the methyl groups point to the outside, silcones form hydrophobic films with good release properties, particularly if the film is cured after application. In fact, PDMS has one of the lowest critical surface tension of all polymers which is in the range of 20 to 25 mN/m and comparable to that of Teflon (PTFE). Thus polyalkylsiloxanes are capable of wetting most surfaces, unless some of the methyl groups are replaced by more polar groups.

Due to the low rotation barriers, most siloxanes are very flexible. For example, the rotation energy around a CH_2-CH_2 bond in polyethylene is about 12.1 kJ/mol but only 3.8 kJ/mol around a Me_2Si-O bond, corresponding to a nearly free rotation. Furthermore, chain-to-chain interaction is rather week due to the low cohesive energy, and the distance between adjacent chains is noticeably larger in silicones than in alkanes which also contributes to the great flexibility of the silicones. Due to great flexibility of the chain backbone, the activation energy of viscous flow is very low, and the silicone viscosity is less dependent on temperature compared to hydrocarbon polymers.

Despite a very polar backbone, silicones can be compared to paraffin, with a low critical surface tension of wetting. In fact, silicones have a critical surface tension of wetting that is higher than their own surface tension. Thus, silicones are capable of wetting themselves, a property that results in good film formation and good surface covering. The low intermolecular interactions in silicones have many other consequences. For example, the glass transition temperatures are very low (e.g., 146 K for a polydimethylsiloxane compared to 200 K for polyisobutylene, which is the analogue hydrocarbon.) Due to the high free volume compared to hydrocarbons, most gases have a high solubility and high diffusion coefficient in silicones. That is, silicones have a high permeability to oxygen, nitrogen and water vapor, even if in this case liquid water is not capable of wetting the silicone surface! As expected, silicone compressibility is also high.

Many other groups like phenyl, vinyl, alkyl, or trifluoropropyl can substitute the methyl groups along the chain. The simultaneous presence of other organic groups attached to the inorganic backbone leads to many unique properties and allows their use in a broad range of fields. One general drawback of the presence of other organic groups along the chain backbone is the reduction of the polymer's thermal stability. But with these substitutions, many other properties can be (greatly) improved. For example, a small percentage of phenyl groups along the chain reduces the tendency to crystallization and allows the polymer to remain flexible even at very low temperatures. The phenyl groups also increase the refractive index. Trifluoropropyl groups along the chain change the solubility parameter of the polymer from 15.3 $MPa^{1/2}$ to 19.4 $MPa^{1/2}$, which reduces the swelling of silicone elastomers in alkane and aromatic solvents. Silicone copolymers can also be prepared with excellent surfactant properties, with the silicone as the hydrophobic part.

1.4 Uses Of Organopolysiloxane

It is well known that a silicone **oil** or an organopolysiloxane fluid is admixed with a pasty material used as the base of various cosmetic and medicinal preparations such as creams, hair dressings, ointments and the like. The silicone **oil** in these applications is used merely as an additive in a relatively small amount.

1.5 WEAR

Wear refers to the progressive removal of material from a surface and plastic deformation of material on a surface due to the mechanical action of the other surface. The necessity for relative motion between the operating surfaces and initial mechanical contact between asperities leads an important role between mechanical wear compared to other processes with similar outcomes.

Wear is generally described as oxidative, single-cycle or repeated-cycle deformation, abrasive, adhesive or erosive (Allen and Ball, 1996). Wear is the sideways displacement or erosion of material from its parent material and original position on a solid surface performed by the action of another surface.

It is related to interactions between surfaces and more specifically the removal and deformation of material on a surface as a result of mechanical action on the opposite surface. The need for relative motion between two surfaces and initial mechanical contact between asperities is an important distinction between mechanical wear compared to other processes with similar outcomes. Wear is a process of removal of material from one or both of two solid surfaces in solid 3 state contact, occurring when two solid surfaces are sliding or rolling motion together.

The definition of 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.

1.5.1 Factors affecting the wear performance of materials

Wear behavior of a material depends on many factors:- Some of them are mentioned below and is as follows

- Surface of solids, ranging from bulk surface distortion to local microscopic irregularities, exert a strong influence on wear.

- It is highly depends upon the surface material, the shape of the contacting surfaces, environment, operating conditions and also on the type of material of which the components are made. As wear will be very different between tool steel on tool steel and tool steel on aluminum.

- More is the surface roughness; more is the probability of wear.

- The effects of alloying element have a great impact on wear and friction. For example, presence of high sulphur content (about 100 ppm) in the bainitic steels leads to a high fraction of MnS inclusion. The removal of material is enhanced by the presence of such inclusions as they come close to the surface and form open cracks.

- Wear behavior can also greatly affected by crystal structure, grain size, and grain boundaries. The presence of grain boundaries in polycrystalline materials influences friction as well as wear behavior. When sliding motion occurs, surface dislocations are blocked in their movement by a grain boundary and they accumulate at the grain boundary which results in strain-hardening of the surface layers. This action makes 16 sliding motion more difficult and increases frictional force for materials in sliding contact leads to wear of the material.

- The presence of more aggressive atmosphere results in formation of oxides on the worn surfaces. The type of loading is an important factor that means the wear of two objects rubbing together is different than wear occurs due to one object impacts the other.

- Speed, temperature, and lubrication also affect the wear of components.

1.5.2 Wear Mechanism

The several wear mechanisms acting either alone, or simultaneously on a material are as follows:

- Adhesive wear
- Abrasive wear
- Fretting wear
- Surface fatigue
- Corrosive & Oxidation wear
- Erosive wear

1.5.2.1 Adhesive wear

Adhesive wear occurs due to materials adhering or sticking with each other under loading which results in material transfer between the two surfaces or the loss of material from either surface.

Adhesive wear can be found between surfaces during frictional contact and generally refers to unwanted displacement and attachment of wear debris and material compounds from one surface to another.

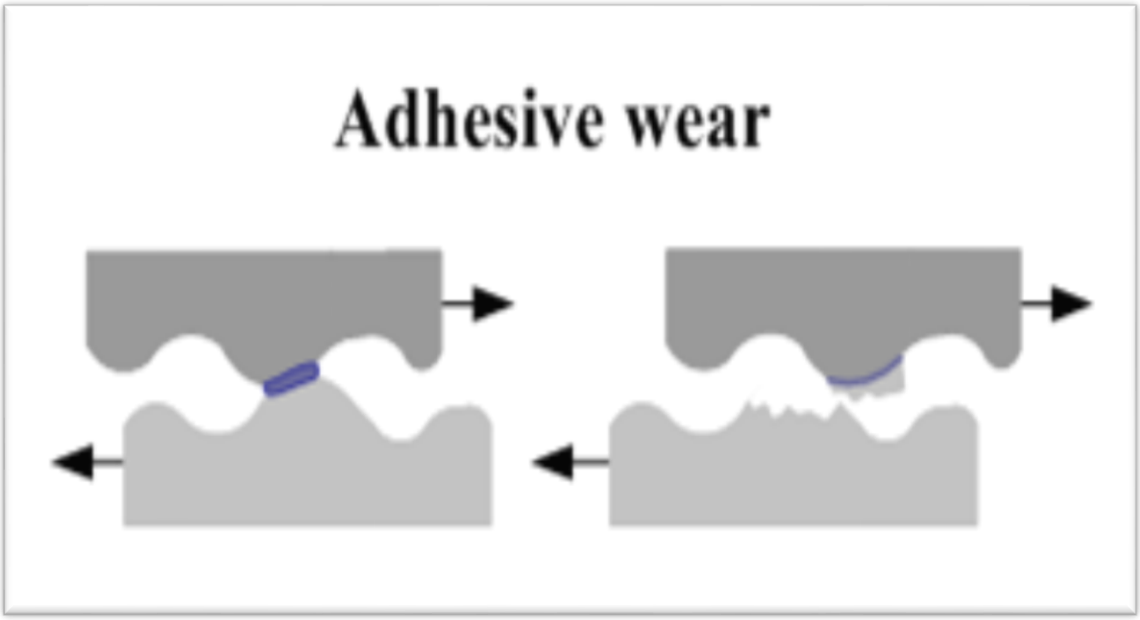


Fig-1.2 Adhesive wear mechanism

1.5.2.2 Abrasive wear

Abrasive wear takes place due to rubbing of softer surface by the harder surface. In the case of ductile materials, hard particles or hard asperities results in plastic flow of softer material. In brittle materials, wear occurs by brittle fracture. Abrasion is categorized depending on the types of contact, as well as contact environment. Depending on the types of contacts, abrasive wear can be classified as two-body and three-body wear. The former occurs due to an abrasive slides along a surface, and the later, due to an abrasive is caught between one surface and another. Figure shows the schematic representation of two body and three body wear mechanisms.

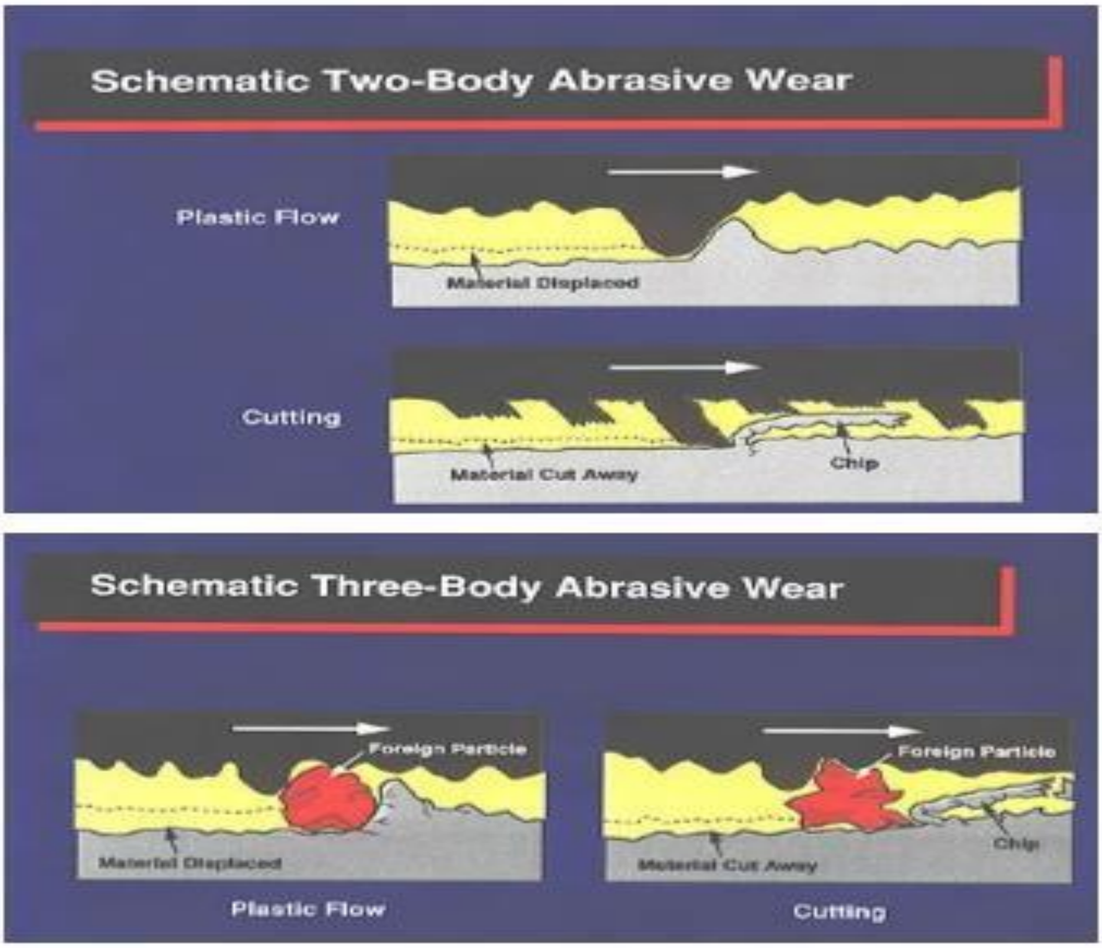


Fig-1.3 Two and three body abrasive wears mechanism

Figure represents some of the processes that are possible in case of abrasive wear. They include plowing, wedge formation, cutting, micro fatigue and micro cracking. Plowing is the process of displacing material from a groove to the sides, away from wear particles. The most severe form of wear for ductile material is cutting. During cutting materials separated from the surface like conventional machining.

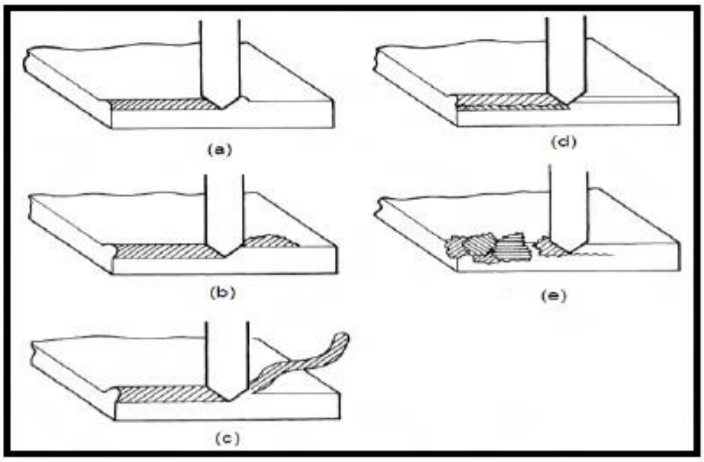


Fig-1.4 Five processes of abrasive wear (a) Plowing (b) Wedge (c) Cutting (d) Micro fatigue (e) Micro cracking

1.5.2.3 Fretting wear

Fretting wear refers to small amplitude oscillatory motion that occurs between contacting surfaces which are usually at rest. The movement is usually because of the external vibration, but in most cases it occurs due to one of the members being in contact subjected to cyclic stress which gives rise to early fatigue cracks. This is known as fretting fatigue. It is affected by different variables such as amplitude of slip, normal load applied on the material, frequency of vibration and also on fretting situation, such as type of contact, mode of vibration and the condition of surfaces. Fretting wear is the repeated cyclical rubbing between two surfaces. It occurs typically in bearings, although most bearings have their surfaces hardened to resist the problem.

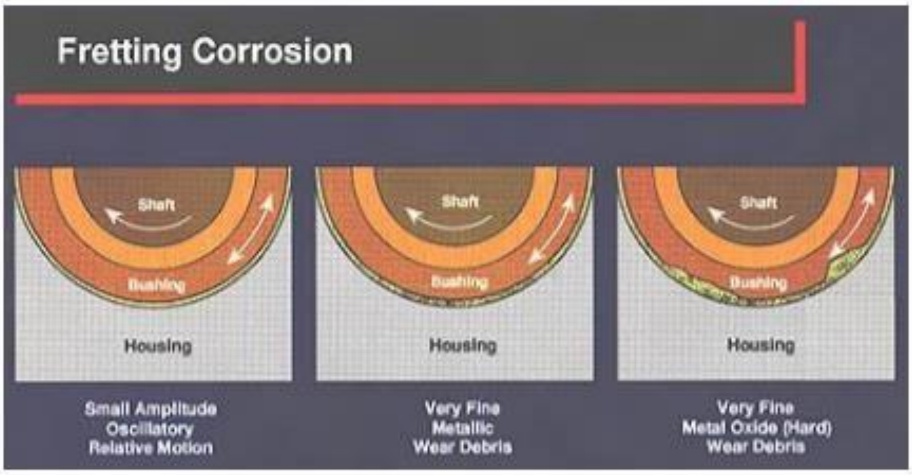


Fig-1.5Fretting wear

1.5.2.4 Surface fatigue

Surface fatigue occurs when surface undergoes repeated cycles of stress. This may be due to sliding or rolling motion of surfaces. When material is subjected to several cycles of stress, there may be crack formation in/near the surface. However, in an interface of materials the contacting stresses are very high and surface fatigue wear mechanism can be operative. Fatigue wear is produced when the wear particles are detached by cyclic crack growth of micro cracks on the surface. These micro cracks are either superficial cracks or subsurface cracks.

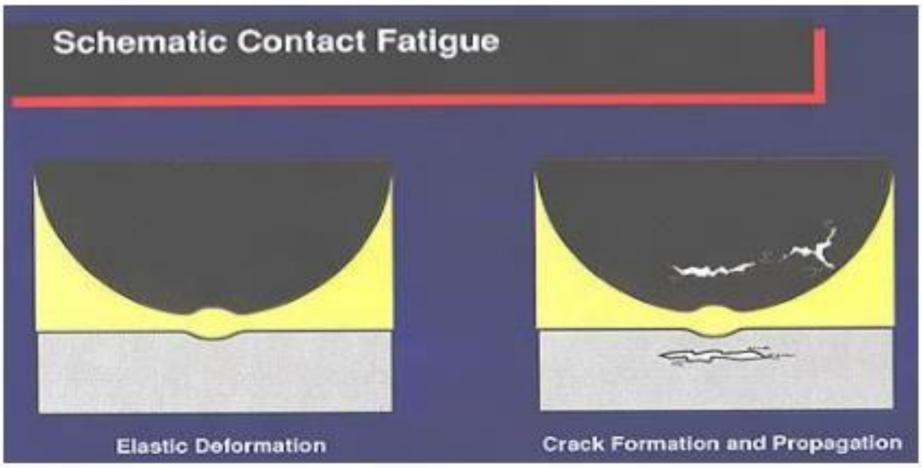


Fig-1.6 Surface Fatigue

1.5.2.5 Corrosive wear

Corrosion and oxidation wear occurs both in lubricated and non-lubricated contacts. The fundamental causes are chemical reactions between the worn material and the corroding medium. Corrosive wear occurs when sliding takes place in a corrosive environment. The most dominant corrosive medium is oxygen. The combined effect of friction and chemical reaction leads to total material losses that are much greater than any of the process taken alone. In the absence of sliding, the chemical products form a protective layer on the surface, which tends to lower the corrosion, but the sliding motion wears the chemical film away, so that the chemical attack continues.

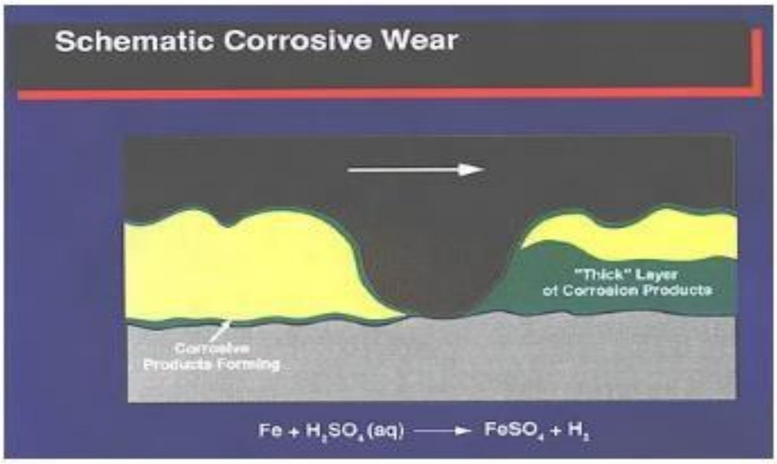


Fig-1.7 Corrosive wear

1.5.2.6 Erosive wear

Erosive wear can be defined as an extremely short sliding motion and is executed within a short time interval. Erosive wear is caused by the impact of particles of solid or liquid against the surface of an object. The impacting particles gradually remove material from the surface through repeated deformations and cutting actions. It is a widely encountered mechanism in industry. Due to the nature of the conveying process, piping systems are prone to wear when abrasive particles have to be transported.

The rate of erosive wear is dependent upon a number of factors. The material characteristics of the particles, such as their shape, hardness, impact velocity and impingement angle are primary factors along with the properties of the surface being eroded. The impingement angle is one of the most important factors and is widely recognized in literature. For ductile materials, the maximum wear rate is found when the impingement angle is approximately 30°, while for non-ductile materials the maximum wear rate occurs when the impingement angle is normal to the surface.

Fig-1.8 Erosive wear

1.5.3 Abrasive Wear Processes

The abrasive wear process has been classified according to three factors.

- The number of bodies involved in the contact, two or three body;
- The stress level; low if the abrasive does not fracture significantly and high if it does;
- Freedom of the abrasive; open if the abrasive is free to move in the direction of the normal load, closed if it is constrained.

Classifications such as two-body and three-body, high- and low-stress conditions have been developed over the years to describe abrasion processes in order facilitate meaningful discussion.

1.5.3.1 Two and Three-body Abrasion Wear

In abrasive wear, material is removed or displaced from a surface by hard particles, or sometimes by hard protuberances on a counter face (hard rough surface), forced against and sliding along a soft surface. The nature of abrasive wear is determined by the way which particles traverse the worn surface. Particles may roll and/or slide over the surface. Therefore two basic modes have been identified: two-body and three-body abrasive wear.

Two-body abrasive wear involves the removal of material by abrasive particles which are held fixed (as in abrasive paper) while being moved across a surface. This process produces a grooving form of wear.

Three-body abrasion involves loose particles which may rotate as well as slide as they contact the wearing surface. Compared to two-body abrasion, three-body abrasion is much more common and also much more complicated than two-body abrasion. Plastic indentation wear will be much more important in three-body abrasion than that in two- body abrasion. Furthermore, in three body abrasion, the movement patterns of abrasives are more complicated than in two body abrasion, since the abrasives not only slide, but also roll. Thus, a relatively wide range of wear rates have been variously reported for three-body abrasion conditions, which depend not only on the material being tested, but also on the testing apparatus. In three-body abrasion of metals, cutting wear and plastic deformation wear coexist. As a consequence, two-body abrasion tests are said to produce wear rates one to three orders of magnitude higher than three- body abrasion under comparable loading conditions.

1.5.3.2 Two and Three-body Abrasion Wear

Misra and **Finnie** proposed a further subdivision of three-body abrasion into ―closed‖ and ‖open‖ groups. The closed group covers the cases of fine abrasives between closely mating surfaces. Open three-body abrasion covers cases where there is a thick bed of abrasive, or the particles are so large, that the two-opposed surfaces are so far apart that the mechanical properties of one have no influence on the other.

1.5.4 Mechanisms of Abrasive Wear

Several mechanisms have been proposed to explain how material is removed from a surface during abrasion. These mechanisms include plastic deformation, fracture, fatigue, grain pull-out and corrosion. In order to understand abrasive wear in simple terms, these mechanisms shall be separated into the two main mechanisms: plastic deformation and fracture. Under some circumstances, plastic flow may occur alone, but because of the complexity of abrasion, rarely does one mechanism completely account for all the loss. Although the plastic deformation mechanism is often linked with ductile materials and the fracture mechanism is linked with brittle materials, both can occur together

1.5.5 Plastic deformation

Two major processes take place when abrasive particles contact the surface of a relatively ductile material.

- The formation of grooves which do not involve direct material removal.
- The separation of material in the form of primary wear debris or microchips.

In both cases, material is deformed to the side of the grooves and can become detached to form secondary microchips. Ultimately, material is removed by fracture, but plastic deformation processes control the rate at which material is removed. If fracture did not occur, the material would continue to deform until it was able to elastically support the load on the contacting particles.

Robinowicz suggested a simple model for the abrasive wear process by plastic deformation. This model is based on an abrasive particle, idealized as a sharp cone of semiangle θ , being dragged across the surface of a ductile material which flows under an indentation load F. It forms a groove in the material with hardness H, and wear is assumed to occur by removal of some proportion of the material which is displaced by the particle from the groove. The volume of groove V per unit length can be obtained:

$$\frac{V}{L} = \frac{2}{\pi \tan\theta} \frac{F}{H}$$

Therefore, the wear rate Q is defined as:

$$Q = K\frac{F}{H}$$

which is the well-known **Rabinowicz** equation. K is the wear coefficient and defined as:

$$K = \frac{2\eta}{\pi \tan\theta}$$

where η is the fraction of material displaced from the groove. According to the Rabinowicz model, wear in homogeneous materials only depends on the attack angle θ, the normal load F, the hardness H of the material and the geometry of the indenter (in this case a conical indenter). This simple model suggests that the wear rate per length of sliding will be directly proportional to the load, and will vary inversely as the hardness of the surface.

1.5.6 Fracture

Although plastic deformation occurs during abrasive wear of brittle materials, fracture is often the rate controlling mechanism. Even during the wear of ductile materials, fracture may occur. For a ductile material, fracture is most likely to occur just behind a contacting abrasive particle since this region is subject to a tensile stress. The material removal in brittle materials is likely to be controlled by fracture rather than by plastic deformation except during wear by very lightly loaded blunt abrasive particles.

One model for the abrasive wear by fracture is based on the removal of material by lateral cracks which grow upwards to the free surface from the base of the subsurface deformed region and are driven by the residual stresses associated with the deformed material. **Organopolysiloxanens** and **Wilshaw** developed a model using fracture mechanics to describe removal of material by lateral cracking.

In this model, the volume wear rate per unit sliding distance Q is given by:

$$Q = \alpha \frac{F^{5/4} d^{1/2}}{A^{1/4} K_c^{3/4} H^{1/2}}$$

where F, d, A, Kc and H are load, diameter of abrasive particle, contact area, fracture toughness and hardness of material respectively. α is a material- independent constant.

1.5.7 Measurement of wear

The most commonly used techniques to Organopolysiloxaneluate wear are weighing and measurement of changes in dimensions.

The Society for Tribology and Lubrication Engineers (STLE) had published, different number of wear and lubrication tests. The scientific study of wear measurement is to quantify wear. This can be taken in wear mass or wear volume. Most of the test methods have intrinsic limitations and do not state clear picture in general about wear and its mechanisms. This can be attributed to the very complex nature of wear, and also the problems associated with precisely expressing and simulating the wear processes. The magnitude of wear is measured in mass loss. This aspect is of great importance in materials having different wear resistance and different densities, e.g. a weight loss of 28 gm in a sample of cobalt + tungsten carbide (density = 28000 kg/m^3) and a loss of weight of 5.4 g in another alloy of Aluminium (density = 5400 kg/m^3) both have the same magnitude of wear i.e. 1 cm^3 when expressed as a volume loss. The wear resistance is the inverse of volume loss can be used to compare different materials. But due to ease in taking the value in mass, the wear measured in mass loss. The wear tests which are standard in nature are solely used for comparing materials ranking for explicit test criterion as specified in the test method. For more realistic values of material deterioration in industrial applications, it is necessary to conduct wear testing under conditions simulating the exact wear process.

The operating life of an engineering component is expired when dimensional losses exceed the defined tolerance limits. Wear, along with other ageing processes such as fatigue and creep in association with stress concentration factors such as fracture toughness causes materials to progressively degrade, eventually contributing to material failure at an advanced age. Wear in industrial applications is one of a special number of fault factors in which an object loses its usefulness and the economic implication can be of tremendous value to the industry.

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

2.1 Problem Statement

The review study on wear showed the strengths and findings of various mathematical models. The investigation of the same should be utilized to allow new work to progress and therefore improve our knowledge. It is in the view of this author that a multi- orientational set-up is need of the hour, so that wear should be checked at different angular position , this will not only add the new dimension to study the wear but will also gives the better understanding of wear behavior of different metal at different orientation. This approach might be very different and new when compared to approaches discussed earlier in different models. A comprehensive literature review was done according to problem selected, due to the uniqueness of the same, it was decided that research paper concerning abrasive wear will be taken into consideration.

2.2 Literature Reviews on Abrasive Wear

- **S. Vishvanathperumal** reported that Carbon black and silica have been used as the main reinforcing fillers that increase the usefulness of rubbers. In this work the effect of carbon black (high abrasion furnace)/silica hybrid fillers on the mechanical properties, crosslink density and morphological behaviour of ethylene vinyl acetate (ORGANOPOLYSILOXANE) was investigated. ORGANOPOLYSILOXANE reinforced with 0/50, 10/40, 20/30, 30/20, 40/10 and 50/0 phr of carbon black (CB)/silica hybrid filler. The total hybrid filler is kept constant at 50 phr (parts per hundred rubbers) and six different compounds were prepared. ORGANOPOLYSILOXANE, CB and silica followed by compounding on a two roll mill and molding at 180°C and 20 megapascal (MPa) pressure. The mechanical properties such as tensile & tear strength, elongation at break and 100% modulus have been measured at 23°C on universal testing machine. Abrasion resistance, hardness and rebound resilience are studied using DIN abrader, Shore A durometer and vertical rebound resilience respectively. The tensile strength, modulus, tear strength, abrasion resistance, hardness and crosslink density increased with the CB filler content in hybrid filler, reached the maximum value at 50 phr of high abrasion furnace carbon black. Morphological properties of composites were Organopolysiloxaneluated by scanning electron microscopy analysis.

- **Tham Do Quang** reported that the dispersibility of ethylene vinyl acetate copolymer (ORGANOPOLYSILOXANE)/silica nanocomposites (for the ORGANOPOLYSILOXANE/silica nanocomposites and interaction between silica nanoparticles (nanosilica) and ORGANOPOLYSILOXANE by adding ORGANOPOLYSILOXANE-g-acrylic acid (ORGANOPOLYSILOXANEgAA) as a compatibilizer, which was formed by grafting acrylic acid onto ORGANOPOLYSILOXANE chains with the aid of dicumyl peroxide). The above nanocomposites with and without ORGANOPOLYSILOXANEgAA were prepared by melt mixing in a Haake intermixer with different contents of silica and ORGANOPOLYSILOXANEgAA. Their structure and morphology were characterized by Fourier transform infra-red (FT-IR) spectroscopy, field emission scanning electron microscopy (FE-SEM), and the mechanical, rheological, dielectrical, and flammability properties of the nanocomposites were also investigated. The FT-IR spectra of the nanocomposites confirmed the formation of hydrogen bonds between the surface silanol groups of nanosilica and C=O groups of ORGANOPOLYSILOXANE and/or ORGANOPOLYSILOXANEgAA. The presence of ORGANOPOLYSILOXANEgAA remarkably increased the intensity of hydrogen bonding between nanosilica and ORGANOPOLYSILOXANE which not only enhanced the dispersion of nanosilica in ORGANOPOLYSILOXANE matrix but also increased the mechanical, viscosity and storage modulus of ORGANOPOLYSILOXANE/silica nanocomposites. In addition, the flammability of ORGANOPOLYSILOXANE/silica nanocomposites is also significantly reduced after the functionalization with ORGANOPOLYSILOXANEgAA. However, the mechanical properties of ORGANOPOLYSILOXANE/silica nanocomposites tended to level off when its content was above 1.5 wt.%. It has also been found that the dielectric constant value of the ORGANOPOLYSILOXANE/ORGANOPOLYSILOXANEgAA/silica nanocomposites is much lower than that of the ORGANOPOLYSILOXANE/silica nanocomposites, which is another evidence of the hydrogen bonding formation between ORGANOPOLYSILOXANEgAA and nanosilica.
- **P. Sampathkumaran** reported that Fiber/filler reinforced polymer composites are known to possess high strength and attractive wear resistance in dry sliding conditions. How these composites perform in abrasive wear situations needs a proper understanding. Hence, in this research article the mechanical and three-body abrasive wear behaviour of E-glass fabric reinforced epoxy (G-E) and silicon carbide filled E-glass fabric reinforced epoxy (SiC-G-E) composites are investigated. The mechanical properties were Organopolysiloxaneluated using Universal testing machine. Three-body abrasive wear tests are conducted using rubber wheel abrasion tester wherein two different loads and four varying abrading distances are employed.

The results showed that the wear volume loss is increased with increase in abrading distance and the specific wear rate decreased with increase in abrading distance/load. However, the presence of SiC particulate fillers in the G-E composites showed a promising trend. The worn surface features, when examined through scanning electron microscopy, show higher levels of broken glass fiber in G-E system compared to SiC- filled G-E composites. POLYM. COMPOS., 2008. © 2008 Society of Plastics Engineers

- **Pramila Baiet. al.** reported ―that Si additions (4-24%Si) improved wear resistance of aluminium, no relationship between wear rate as a function of Si content was found. Wear rate increased linearly with applied pressure but was independent of sliding velocity. The value of the friction coefficient was found to be insensitive to applied pressure, Si content and sliding velocity. The fact that no transition in wear mechanism was observed with increased pressure, as reported by other authors could be due to the narrow range explored (0.105-1.733 MPa)‖.
- **Liang Y. N. et. al.** reported that the MMCs containing SiC particles exhibit improved wear resistance. Particle size is one of the most important factors in determining wear of particulate-reinforced metal composites. However, it appears to be difficult to draw a fundamental conclusion from the reports about this problem. Some reports have suggested that wear resistance of the composites increased with increasing particle size, while others indicated that an increase in particle size had a negligible influence on the wear rate. A further problem is that nearly all the studies have been carried out with such methods as pin on disc or sand rubber wheel abrasion tests, in which the sliding speed was maintained in a narrow range and the applied load in a steady state. It is thus necessary to study the effect of particle size on wear properties of the composites under a variety of experimental conditions. In this work , the effect of particle size on wear behavior of SiC particulate-reinforced 2024 Al composites has been investigated using three tests : sliding wear , impact abrasion and erosion.
- **H.C. How and T.N. Baker** In their investigation of wear behavior of Al6061- saffil fiber, concluded that ―saffil are significant in improving wear resistance of the composite‖.The steady-state wear of aluminium alloy AA6061 and AA6061-based Saffilfibre-reinforced composites, manufactured by a PM route, was investigated with a pin-on- disc configuration under dry sliding conditions. Using a constant sliding velocity, the wear rates of the monolithic alloy and the composites increased proportionally with the applied load. The benefit of Saffil reinforcement at volume fractions of 5, 10 and 20% was not substantial at loads ranging from 4.9 to 48.3 N. As the applied load decreased to 1.1 N, the composite showed a promising improvement in wear resistance as the volume fraction

of Saffil reinforcement increased. At loads of 19.2 N and above, the wear resistance of the AA6061 composite was slightly impaired when the volume fraction of the Saffil reinforcement was increased from 5 to 20%. Compared with over-aged samples, the improvement of the wear resistance due to peak-ageing was not significant, although the Vickers hardness of the peak-aged samples was double that of the over-aged samples. The surface morphology of both the monolithic alloy and the composites after testing under loads of 9.8 or 48.3 N revealed a compacted layer which comprised mainly aluminium and iron. The amount of iron transferred increased with the applied load and with the volume fraction of Saffil in the composite. Energy Dispersive X-ray (EDAX) analysis indicated that the wear debris was generated mainly from the compacted layer. On the basis of the experimental observations, delamination was considered to be the controlling wear mechanism for the monolithic specimens tested at all loads and the composite specimens tested at loads ranging from 4.9 to 48.3 N. At a load of 1.1 N, surface fatigue, which caused surface cracking, was evident for the composite specimens.

- **R. Dasgupta, R. Thakur, and B. Govindrajan** concluded in their study that ―the high stress wear behavior is dependent on the combination of a number of experimental factors. The behavior can be explained based on the material removal mechanism operating under a combination of experimental factors. A regression analysis of the experimental data shows that the dependence is nonlinear. The equation arrived at by regression analysis helps in predicting the wear rate. A comparison between the experimental and predicted observed values indicates a variation of ±15%. Such an analysis should aid in predicting the high stress abrasive wear behavior of steels exposed to various combinations of load, particle size, and sliding distances‖.
- **M.S. Zaamout** the objective of this research is to investigate the abrasive wear behaviour of polymer base auto motive paint, which is locally used for steel painting. Research has been conducted under dry, water lubricated, and water-soap lubricated conditions. The effects of applied load, sliding distance, abrader surface roughness, and paint drying time on the abrasive wear volume and abrasive wear rate were investigated under controlled environment of 23 C temperatures and 40% humidity. The examined paint was used directly on steel substrate with no primer. Preliminary results show that wear volume increases with increasing applied load, sliding distance and abrader roughness. However, results also show decreasing wear volume with increasing drying time up to 50 hr. Beyond this value, time seems to have little effects on abrasive wear behaviour. This argument is valid for all four conditions of tests. As for abrasive wear rate, results show decreasing abrasive wear rate with applied load , sliding distance, abrader surface roughness, and drying time. Results clearly indicate that the presence of water significantly increases the wear volume and wear rate. Furthermore, the addition of soap to water increases the wear volume and rate to even higher levels.

- **L.J. Yang** in their study found that the Wear coefficient values obtained from different investigators can vary significantly up to a deviation of 1000% due to lack of a standard test method. Higher wear coefficient values can be obtained when the wear tests are carried out within the transient wear regime, or with an excessive sliding distance in the steady-state wear regime.
- **Basavarajappa S. and Chandramohan G** reported that the sliding distance has the highest effect on the dry sliding wear behavior of MMCs than that of the load and sliding speed‖.
- **Y. Reda et.al** studies on Al6061-SiC and Al7075 - Al2O3 Metal Matrix Composites and **R. Clark et.al** in their studies on Al7075 reported that ―pre-aging at various retrogression temperatures improves the hardness, tensile properties and electrical resistivity‖.
- **Q Wang, Z H Chen, Z X Ding and Z L Liu** –Conducted study on Performance of abrasive wear and erosive wear of WC-12Co coatings sprayed by HVOF. They used WC-Co cermets as wear resistant materials. Their work examines the performance of such conventional and nano-structured materials in the form of coatings deposited by high velocity oxy-fuel (HVOF) thermal spraying. The results indicated that: microstructures of nano-structured and multimodal WC-12Co coatings prepared by HVOF are dense with little porosity, and their microhardness values are obviously higher than conventional WC-12Co coatings, though Nano WC did during spraying. As well, it was found that nanostructured and multimodal WC-12Co coatings exhibited better abrasive and erosive wear resistance in comparison with conventional one.
- **B. Sidda Reddy, G. Padmanabhan and K. Vijay Kumar Reddy** in their study deals with the development of a surface roughness prediction model for machining aluminum alloys using multiple regression and artificial neural networks. The experiments have been conducted using full factorial design in the design of experiments (DOE) on CNC turning machine with carbide cutting tool. A second order multiple regression model in terms of machining parameters has been developed for the prediction of surface roughness. The adequacy of the developed model is verified by using co- efficient of determination, analysis of variance (ANOVA), residual analysis and also the neural network model has been developed using multilayer perception back propagation algorithm using train data and tested, using test data. To judge the efficiency and ability of the model to predict surface roughness values percentage deviation and average percentage deviation has been used. The experimental results show, artificial neural

  model predicts with high accuracy compared with multiple regression model. This study uses statistical multiple regression model for prediction of surface roughness in machining of aluminum alloys, which is used to determine the correlation between a criterion variable and a combination of predicted variables. It can be used to analyze data from any of the major quantitative research designs such as fundamental comparative, correctional and experimental.

This method is also able to handle interval ordinal or categorical data and provides estimates both of the magnitude and statistical significance of the relationships between variables (Gall et al., 1996). Therefore, multiple regression analysis will be helpful to predict the criterion variable finish surface roughness via predictor variables, such as spindle speed, feed and depth of cut. The second order multiple regression model for the surface roughness(Ra, μm) is developed as a function of cutting parameters such as cutting speed (V), federate (f) and depth of cut (d). This analysis is carried out at a significance level of 5% i.e., confidence level of 95%. The optimal neural network architecture was used in this study.

It was designed using NEURO SOLUTIONS 5.0. The network consists of one input, two hidden and one output layer. Hidden layers have eight neurons each, where as the input and output layers have three and one neuron, respectively. Using full factorial design in the design of experiment, the machining parameters which are influencing the surface roughness on the machining of Al Alloys has been modeled using Multiple Regression and Artificial Neural Networks.

It concluded that:

(a) The Multiple Regression Model is developed to predict the Surface Roughness for Turning of Al Alloys and the predicted model was tested with three sets which were never used in modeling and average percentage deviation calculated as 8.76%.

(b) The neural network model is developed to predict surface roughness and predicted model was tested using the same test data which were used in Multiple Regression Model and the Average Percentage Deviation was calculated as 0.9853%.

(c) After analyzing the Multiple Regression Model and Artificial Neural Network Model, the Artificial Neural Network Model has good prediction capability and has given minimum percentage deviation compared to the Multiple Regression Model.

- **S.S. Mahapatra and VedanshChaturvedi** found that the hardness of the composite monotonically decreases as the fibre length increases but tensile strength first increases and then decreases as length of the fibre is increased. In contrary to common belief that hardness and tensile strength improve wear resistance, it has been observed that parameters encountered in wear process strongly influence wear resistance. In future, the study can be extended to other natural fibres to find out the optimum fibre length. The abrasive wear behavior of chemically treated sugarcane fibre and aging effects of the fibre on abrasive behavior of the composite can be studied‖.
- **Sagbas, F. Kahraman, U. Esme** studied the –modeling and predicting abrasive wear behavior of poly oxy methylenes using response surface methodology and neural networks and found that

the abrasive wear behavior of poly oxy methylenes (POM) under various testing conditions was investigated. A central composite design (CCD) was used to describe response and to estimate the parameters in the model. Response surface methodology (RSM) was adopted to obtain an empirical model of wear loss as a function of applied load and sliding distance. Also, a neural network (NN) model was developed for the prediction and testing of the results. Finally, a comparison was made between the results obtained from RSM and NN‖.

- **J. L. Xuan, I. T. Hong and E. C. Fitch** Under fluid film lubrication, the particulate contaminants in the fluid cause three-body abrasive wear on critical surfaces. The wear not only depends on the hardness of the wearing surface (Hj), but also on the hardnesses of its opposing surface (Hb) and the involved abrasives (Ha). In this paper, the hardness effect, particularly the relationships among these three hardnesses, is studied, by exploring the interdependence between two hardness ratios: the ratio between two rubbing surfaces (Hb /Hj) and the ratio between the surface to be protected (usually the harder surface) and the abrasives (Hj /Ha). Three types of journal-bearing pairs (Hb /Hj = 0.75, 0.6, and 0.3) were tested, subjected to four abrasive particles (Hj /Ha ranges from 0.14 to 2.75). The wear linearly varies with the Hj /Ha value at each metal hardness ratio on log-log diagram. The empirical constants in the wear function are obtained. The critical hardness ratio and the wear coefficient are also analyzed.

- **Chang Chongyi Wang Chenggu and Jin Ying** conducted their study on numerical method to predict wheel/rail profile evolution due to wear. ―A wheel/rail profile wear prediction methodology was developed and applied to the wheel/rail disc test about the wear of flange and gauge. Three-dimensional nonlinear finite element dynamic analysis code ABAQUS was also used in the simulation of wheel/rail disc rolling contact process. The simulation results are compared with measurements of laboratory wear test and the effectiveness of the wear prediction methodology was verified‖.
- **Friedrich Franek, Ewald Badisch and Martin Kirchgaßne** In many fields of industry, abrasion and erosion processes are dominant wear mechanisms that reduce lifetime of costly machine parts. Wear resistance against abrasion and/or impact or the ability to withstand other complex mechanical actions are often required. In order to quantify the specific properties of material that are applied in such fields, several test methods are in use. A certain discrepancy can be seen between the systems approach and the aim to get information about suitability of materials for

practical applications simply from specific material tests. This paper gives an overview over a selection of relOrganopolysiloxanent test equipment and procedures. In addition, some examples are given for advanced studies on materials behavior combining tribological test, material analyses respectively materialography, and mathematical methods in order to support – for selected cases – the acquired correlation of materials properties and wear resistance under severe conditions.

- **Dharma R. Maddala, Arif Mubarok and Rainer J. Hebert** conducted study on Sliding wear behavior of Cu50Hf41.5Al8.5 bulk metallic glass. Sliding wear behavior of a copper-based bulk metallic glass (Cu50Hf41.5Al8.5) was investigated for both as-cast and annealed samples. ―The wear resistance increased during isothermal annealing near the glass transition temperature. Nano-crystals developed during the annealing for annealing times up to 300 min. A linear relation between hardness and wear resistance was observed during the early stages of devitrification, but at longer annealing times the wear resistance increased less than the hardness‖.
- **N R Prabhu Swamy, C S Ramesh and T Chandershekar** ―Studied the effect of heat treatment on strength and behavior of Al-SiCp composites and concluded that microhardness of composites increased significantly with increased content of SiCp. Heat treatment has a significant effect on microhardness of Al6061 matrix alloy and its composites. Tensile strength of composites increased significantly with increased content of SiCp. Abrasive wear loss of composites decreases, with the increase in content of SiCp in matrix alloy under identical test conditions‖.
- **Veeresh Kumar G.B, C.S.P.Rao, Bhagyashekar M.S, Selvaraj. N** Reported that ―artificial neural network (ANN) can be effectively applied to study the tribological behavior. The studies conducted regarding wear resistance properties of Al6061-SiC & found that the ANN model can predict the Wear Factor and Wear Height Loss up to 95% accuracy‖.
- **Dushyant Singh, K P Saha & D P Mondal** conducted their study on development of mathematical model for prediction of abrasive wear behavior in agricultural grade medium carbon steel and found that ―the wear rate of ICA and QT specimens are much lower than that of AR and AN specimens due to formation of ferreto-martensitic, and tempered martensitic structure respectively during heat- treatment process. Wear rate follows a non-linear relationship with peening intensity as at first it is reduced up to a peening intensity of 0.17 A, then increases again with the increase in peening intensity due to increase in brittleness of the specimen with the peening intensity. Applied load, however the rate of growth may vary according to heat treatment

applied to the material. The complex relationship between the influencing factors and wear rate can be illustra-ted by fitting a mathematical equation of quadratic form which shall help in prediction of wear rate accurately as the corresponding regression coefficients and the model are found to be highly significant‖.

- **Jankauskas, V.; Skirkus, R.; Martinkus, N.** Industrialized countries studies have shown that because of wear in the world suffered huge losses every year - up to 4% of the gross national product. It was found that investments in the tribological research

  annually can save from 1 to 1.4% of gross national product. In this paper, the abrasive wear research of arc welded Fe-C-Si-Cr-Ti-B surfaces into embedded abrasive.

  The microhardness of arc welded layers has a direct impact on abrasion - the harder layers, the higher resistance to abrasive wear. In SEM picture visible cutting traces of wear and only small fragments are chipped. This phenomenon demonstrates the high abrasive and metal microhardness differences influence. The highest wear resistance shows sample with C - 1,6%, Cr - 4,4%, B - 0,56%, Mn - 0,9%, Si - 1,44%, Ti - 0,59% and Fe - 90,2%.
- **Punyapriya Mishra** studied the ‒statistical analysis for the abrasive wear behavior of bagasse fiber reinforced polymer composite and found that the relationship of abrasive wear loss with fiber concentration, applied load and sliding velocity has been successfully obtained by using RSM at 95% confidence level. The response surface methodology analysis has been reviewed. RSM can be used for the approximation of both experimental and numerical responses. Two steps are necessary, the definition of an approximation function and the design of the plan of experiments. This model is valid within the ranges of selected experimental parameters of fiber concentration, applied load and sliding velocity. The accuracy of the RSM model was verified with three sets of experimental data which were never used in modeling and average percentage deviation calculated as 7.542%.
- **E. Y. H. Bobobee and F. Kumi** Develop and Organopolysiloxaneluate equipment for testing the abrasive wear off tillage tools in the laboratory. The abrasive wear experiment was arranged in a completely randomized design with the soils from the five sites as the treatment. Each treatment was replicated five times. The wear rate of soils from Akatsi and Ho showed increasing trend with increasing moisture content while that of Wenchi and Mampong showed a reverse trend up to 13% and 15% moisture content, respectively. The soil from Akatsi produced the highest wear of 4.11g. The wear in the soils from Ho, Mampong, Wenchi and KNUST were 3.16g, 2.90g, 2.88g and 1.36g, respectively with the least wear from the KNUST soil. This confirms the long held

belief that the wear rate of tillage tools is directly related to the sand content of the soil. The abrasive wear characteristics of the soils showed strong correlation between mass loss and dimensional loss of the ploughshare.

- **M. Sudheer, N. KarthikMadhyastha, M. KewinAmanna, B. Jonthan, and K. MayurJayaprakash** The present work reveals the effect of the addition of commercial MoS2(10wt%) particles on mechanical and two-body abrasive wear behavior of epoxy with/without glass fiber mat reinforcement. The abrasive wear testing was carried out using pin-on-disc wear tester for different loads and abrading distances at constant speed of 1m/s. A significant reduction in wear loss and specific wear rate was noticed after the incorporation of MoS2 filler allowing less wear of matrix during abrasion which in turn facilitated lower fiber damage. The worn surface features were investigated through scanning electron microscopy (SEM) in order to investigate the wear mechanisms.
- **T.S. Barrett, G.W. Stachowiak, A.W. Batchelor** The study was done on friction and wear of ultra-high molecular weight polyethylene (UHMWPE) pins sliding against a stainless steel disc were measured for sliding speeds ranging from 1.25 to 10 m s−1 and disc surface roughnesses Ra from 0.07 to 0.53 μm ms−1. Frictional heating was controlled by air jets and surface temperature measured with an IR pyrometer. It was found that the wear of UHMWPE is critically dependent on surface temperature and that, when the temperature exceeds a critical value, wear proceeds in a series of discrete steps caused by the sudden loss of a molten or softened layer of polymer. Wear was also influenced by surface roughness. An optimum surface roughness, i.e. a minimum of wear was found at low and medium sliding speeds. At the highest speed tested, however, the influence of roughness on wear rate was much less distinct. Scanning electron photomicrographs of worn pins and disc surfaces revealed evidence of melting by UHMWPE at high sliding speeds and abrasion at high surface roughnesses. Transfer films on disc surfaces were limited to isolated deposits of polymer wear particles.
- **D. Kakas, B. Skori C, S. Mitrovi C, M. Babi C, P. Terek, A. Mileti C , M. Viloti C** The influence of applied load and sliding speed on the tribological performance,

  i.e. friction and wear of TiN IBAD coating in sliding with corundum ball has been Organopolysiloxaneluated using reciprocating sliding wear test. Post characterization of wear zones was conducted using AFM, SEM and EDX. The results show that coefficient of friction decrease with decreasing applied load and with increasing the sliding speeds.

- **O. P. Modi, R. P. Yadav, D. P. Mondal, R. Dasgupta, S. Das, A. H. Yegneswaran** in their study of two body abrasive wear behaviour of a zinc-aluminium alloy - 10% Al2O3 composite at different loads (1–7 N) and abrasive sizes (20–275 ^{1}m) as a function of sliding distance and compared with the matrix alloy. The wear rate of the composite and the matrix alloy has been expressed in terms of the applied load, abrasive size and sliding distance using linear factorial design approach. The study suggests that the wear rate of the alloy and composite follow the following relations:

Y alloy $D = 0.1334 - 0.0336x_1 + 0.0907x_2 + 0.0219x_3 - 0.0296x_1x_2 + 0.0274x_2x_3 - 0.0106x_3x_1 - 0.0201x_1x_2x_3$.

Y comp $D = 0.0726 - 0.028x_1 + 0.062x_2 + 0.03x_3 - 0.024x_1x_2 + 0.028x_2x_3 - 0.016x_3x_1 - 0.014x_1x_2x_3$.

where, x1, x2 and x3 are the coded values of sliding distance, applied load and abrasive size respectively. It has been demonstrated through the above equations that the wear rate increases with applied load and abrasive size but decreases with sliding distance. The interaction effect of the variables exhibited a mixed behavior towards the wear of the material. It was also noted that the effect of load is less prominent for the composite than the matrix alloy while the trend reversed as far as the influence of the abrasive size is concerned.

- **Hua-Nan Liu, KeisakuOgi** In this study the tribological properties of Al2O3 continuous fibre reinforced Al-4.43 wt %Cu alloy composites with a fibres volume fraction of about 0.55 were measured for five types of fibre orientations under a dry sliding contact with a bearing steel. Fibres were in a plain perpendicular to wear surface and parallel to sliding direction, and had the angles 0o, 45o, 90o, or 135owith respect to the direction of motion of the counter face; or were anti-parallel the sliding direction. The results show obvious dependence of wear characteristics on fibres orientation: for the 45o, 90o, and 135o orientations, the larger the fibres angle, the lower the volume loss; while the 0oorientation resulted in a higher steady-state wear rate than those of the 45o, 90o, and 135o, orientations, except that the anti-parallel orientation caused the highest volume loss at all sliding distances. The wear mechanism was inferred as a oxidation-microgrooving process through the analyses of worn surface and subsurface with the aid of optical microscope and scanning electron microscope. Also it was found that the fibres broken and subsurface deformation had played an important role in causing wear anisotropy.
- **Gun Y Leec, C.K.H Dharan,R.O Ritchie** A simple physically- based model for the abrasive wear of composite materials is presented based on the mechanics and mechanisms associated with sliding wear in soft (ductile)- matrix composites containing hard (brittle) reinforcement particles. The model is based on the assumption that any portion of the reinforcement that is removed as wear debris cannot contribute to the wear resistance of the matrix material. The size of this non-contributing portion (NCP) of reinforcement is estimated by modeling three primary wear mechanisms, specifically, plowing, cracking at the matrix/reinforcement interface or in the reinforcement, and particle removal. Critical variables describing the role of the reinforcement,

such as relative size, fracture toughness and the nature of the matrix/reinforcement interface, are characterized by a single contribution coefficient, C. Predictions are compared with the results of experimental two-body (pin-on-drum) abrasive wear tests performed on a model aluminum particulate-reinforced epoxy-matrix composite material.

- **D. Tao, G. L. Chen, and B. K. Parekh** A statistical Box-Behnken design (BBD) of experiments was performed to Organopolysiloxaneluate effects of individual operating variables and their interactions on the wear rate of grinding ball mills used in the phosphate industry. The wear tests were conducted using a specially designed grinding mill. The variables examined in this study included grinding time, solution pH, rotation speed, mill crop load, and solids percentage. The most significant variables and optimum conditions were identified from a statistical analysis of the experimental results using response surface methodology. Experimental results show that solution pH has the most significant effect on the wear rate for both Type 1018 (UNS G10180) carbon steel (CS) and a high- chromium alloy. The optimum process parameters for minimum wear rate were solution pH at 7.36, rotation speed at 70.31 rpm, a solid percentage at 75.50, and a crop load at 71.94% for Type 1018 CS; for the high-chromium alloys, they include a solution pH at 8.69, rotation speed at 61.13 rpm, a solid percentage at 64.86, and a crop load at 57.63%.

- **A.A. Torrance** In his study the abrasive wear rates of materials may be very simply related to their mechanical properties, provided wear takes place under very simple conditions. However, wear rates in many practical situations can be controlled by effects which either relate to mechanical properties in more subtle ways, or which are controlled by quite different parameters. Mechanics models of the abrasive process provide a means of linking these different effects together to understand better the effects, which may determine wear under particular conditions. They can also help to design tests to measure the properties of a material under conditions similar to those pertaining in abrasion. Some progress has been made in producing integrated models of real abrasive processes, but much more could be done to improve existing models and develop new ones.
- **S. Kumar , V. Balasubramanian** This paper reports the dry sliding wear behavior of AA7075 aluminium/SiCp composites fabricated by powder metallurgy technique. Five factors, five levels, central composite, rotable design matrix is used to optimize the required number of experiments. The wear test has been conducted in a pin- on-roller wear testing machine, under constant sliding distance of 1 km. An attempt has been made to develop a mathematical model by response surface method (RSM). Analysis of variance (ANOVA) technique is applied to check the validity of the developed model. Student's t-test is utilised to find out the significance of factors. The effects of volume percentage of reinforcement, particle size of reinforcement,

applied load, sliding speed and hardness of counter part materials on dry sliding wear behavior of AA7075 aluminium/SiCp have been analysed in detail.

- **Kleber S. Cruz, Elisangela S. Meza, Frederico A.P. Fernandes, Jose´ M.V. Quaresma, Luiz C. Casteletti, And Amauri Garcia** The aim of the present study was to contribute to a better understanding about the relationship between the scale of the dendritic network and the corresponding mechanical properties and wear behavior. The Al-Sn (15 and 20 wtpctSn) and Al-Si (3 and 5 wtpct Si) alloys were directionally solidified under unsteady-state heat flow conditions in water-cooled moulds in order to permit samples with a wide range of dendritic spacings to be obtained. These samples were subjected to tensile and wear tests, and experimental quantitative expressions

  correlating the ultimate tensile strength (UTS), yield tensile strength, elongation, and wear volume to the primary dendritic arm spacing (DAS) have been determined. The wear resistance was shown to be significantly affected by the scale of primary dendrite arm spacing. For Al-Si alloys, the refinement of the dendritic array improved the wear resistance, while for the Al-Sn alloys, an opposite effect was observed, i.e., the increase in primary dendrite arm spacing improved the wear resistance. The effect of inverse segregation, which is observed for Al-Sn alloys, on the wear resistance is also discussed.
- **J.J. Coronado** In this study, white cast iron with 7.39% Cr was casted into an exothermic mold on a copper chill plate to solidify unidirectionally. The microstructure is composed of oriented M3C carbides and ledeburitic matrix. The specimens were cut both parallel and transversally to the billet axe and pin-abrasion tests were carried out using fixed alumina abrasive grains at loads between 2 and 15 N. The microhardness, elastic modulus and fracture toughness were determined using an indentation technique on transversal and longitudinal directions. The abrasion resistance was correlated with the carbides microhardness and fracture toughness. The M3C carbides showed similar values of fracture toughness in both directions. The carbides in transversal direction showed higher hardness and elastic modulus than longitudinal carbides. The results reveal that for lower loads the mass loss is similar in both directions. However, for loads higher than 10 N the M3C carbides in the transversal direction show higher abrasion resistance than longitudinal carbides. The wear surface was examined by scanning electron microscopy for identifying the wear micromechanisms. Bending and slip planes on longitudinal cementite were

observed at 15 N.

- **Raviraj Shetty ,Raghuvir Pai , Srikanth S. Rao and Vasanth Kamath** This paper discusses the use of Taguchi‘s design of experiments and response surface methodology (RSM) for minimising the surface roughness in turning of discontinuously reinforced aluminium composites (DRACs) having aluminum alloy 6061 as the matrix and containing 15 vol. % of silicon carbide particles with a mean diameter of 25μm under dry cutting condition. The measured results are then collected and analysed with the help of a commercial software package MINITAB15. The experiments are conducted using Taguchi‘s experimental design technique. The matrices of test conditions include cutting

  speed, feed rates and depth of cut. The effect of cutting parameters on surface roughness is Organopolysiloxaneluated and the optimum cutting condition for minimising the surface roughness is determined. A second-order model is established between the cutting parameters and the surface roughness using RSM. The experimental results reveal that the most significant machining parameter for surface roughness is feed, followed by cutting speed. The predicted values and measured values are fairly close, which indicates that the developed model can be effectively used to predict the surface roughness in the machining of DRACs.
- **Satpal Sharma** In the present investigation, Ni–WC composite powder was modified with the addition of CeO2 in order to form a new composition of Ni–WC–CeO2. The Ni–WC and Ni–WC–CeO2 compositions were used for coating deposition by high- velocity oxy-fuel (HVOF) spraying process so as to study the effect of CeO2 addition on microstructure, distribution of various elements, hardness, formation of new phases, and abrasive wear behavior. Further, the effect of load, abrasive size, sliding distance, and temperature on abrasive wear behavior of these HVOF-sprayed coatings was investigated by response surface methodology. To investigate the abrasive wear behavior of HVOF- sprayed coatings four factors such as load, abrasive size (size in micrometers), sliding distance (meters), and temperature (°C) with three levels of each factor were investigated. Analysis of variance was carried out to determine the significant factors and

interactions. Investigation showed that the load, abrasive size, and sliding distance were the main significant factors while load and abrasive size, load and sliding distance, abrasive size and sliding distance were the main significant interactions. Thus an abrasive wear model was developed in terms of main factors and their significant interactions. The validity of the model was Organopolysiloxaneluated by conducting experiments under different wear conditions. A comparison of modeled and experimental results showed 4– 9% error. The abrasive wear resistance of coatings increases with the addition of CeO2. This is due to increase in hardness with the addition of CeO2 in Ni–WC coatings.

- **J.O. Agunsoye, A.A. Ayeni** The effect of heat treatment on the abrasive wear behavior of high chromium cast iron (NF253AHT) under dry sliding condition has been investigated. Rectangular cross-sectioned samples of the alloy were produced by sand

  casting. After casting, the samples were machined to equal dimensions of 50 mm x 15 mm x 10 mm and heat treated by annealing, hardening and tempering. Abrasive wear tests were carried out on the samples using the pin-on-disc wear test. The tests were carried out under restricted values of speed, load and time. Within this limit, the hardened sample displayed a superior wear resistance, while the annealed sample displayed the weakest wear resistance. A graphical model (wear map) displaying all the wear regimes of the alloy, which may serve as a wear predictive tool was subsequently developed from the results of the wear tests. With the exception of the as-cast and annealed specimen, all other specimens (hardened and tempered) have functioned adequately in wear prone environment, but with different degree of effectiveness. Hence, the hardened and tempered samples can be used in shot blast equipments and in the grinding of minerals.
- **S. R. Chauhan and Kali Dass** In this work dry sliding wear behaviour of titanium (Grade 5) alloy has been investigated in order to highlight the mechanisms responsible for the poor wear resistance under different applied normal load, sliding speed, and sliding distance conditions. Design of experimental technique, that is, response surface methodology (RSM), has been used to accomplish the objective of the experimental study. The experimental plan for three factors at three levels using face- centre central composite design (CCD) has been employed. The results indicated that the specific wear rate increases with an increase in the applied normal load and sliding speed. However, it decreases with an increase in the sliding distance and a decrease inthe sliding speed. The worn surfaces of the titanium alloy specimens were analyzed with the help of

scanning electron microscope (SEM), energy dispersive spectroscopy (EDS), and X-ray diffraction (XRD) techniques. The predicted result also shows the close agreement with the experimental results and hence the developed models could be used for prediction of wear behaviour satisfactorily.

- **C Greet, D Obeng, J Kinal and P de Busscher** The dual approach of examining the grinding media wear through a series of marked ball tests and investigating the impact of grinding chemistry on lead and zinc metallurgy using the Magotteaux Mill® at MMG‘s Century mine (Century) has resulted in the conversion of the plant to high chrome grinding media. The consequences of this change have been positive in terms of

  wear, with a reduction in media consumption, and no adverse effect on either the lead or zinc metallurgy.
- **TevfikKüçükömeroğlu, LeventKara** In this study, the sliding friction and wear behavior of copper alloy CuZn39Pb3 were investigated under both atmospheric and vacuum conditions, with the use of an environmentally controlled pin-on-disk apparatus. Experiments were conducted under pressures of 5 x 10-3 mbar , 8 x 10-6 mbar and normal atmospheric conditions (1013 mbar) with contact pressures of 0.3, 1.0 and 2.0 MPa and a 1 m/s constant sliding speed. Scanning electron microscopy was used to characterize the features of the wear surfaces, subsurface regions and debris particles. The wear mechanism of the CuZn39Pb3 alloy was mainly adhesive under both under atmospheric and vacuum conditions; however, some indications of abrasion were observed under atmospheric conditions. The wear rate of the CuZn39Pb3 was lower under vacuum conditions. Furthermore, increasing the applied pressure noticeably increased the wear of the alloy under atmospheric conditions but only slightly increased it under an 8 x 10-6 mbar. Extensive subsurface deformation was observed for the alloy tested in air.
- **O.A. Zambrano, Yesid Aguilar , Jairo Valdés , S.A. Rodríguez , J.J. Coronado** In this study a pin-abrasion test with 220 grit garnet paper as the counterbody, three austenitic steels of different SFEs were compared. The steels were: (i) FeMnAlC, (ii) Hadfield steel, and (iii) AISI 316 L steel. Following a pre-conditioning procedure, the normal loads on the 3 mm diameter test pins were 5 N, 10 N and 15 N, and the sliding speed along a spiral track of total length 430 m was 0.158 m/s. Data showed that the FeMnAlC steel had a higher wear resistance than AISI 316 L steel but lower wear resistance than the Hadfield steel. However, at the highest test load, all three steels had similar wear resistance. The steel with the lowest SFE had the highest abrasive wear

resistance and the steel with the highest SFE had the lowest abrasive wear resistance. The main wear mechanisms were microcutting and microploughing. There was a transition om microploughing to microcutting as the normal load was increased.

- **Yusuke Morioka, Yuki Tsuchiya, Masatoshi Shioya** In this work, the abrasive wear, fatigue, and tensile properties of polyamide 6 (PA6) dispersed with titanium carbide particles, aluminum borate whiskers, and vapor-grown carbon fibers were determined. Moreover, the correlation between them was investigated using the equation Ws=(gf)/(kH), where Ws is the wear rate, g is the shape factor of the abrasive particles, f is the fracture probability, k is a constant, and H is the microhardness. The value of 1/f represents the number of deformation cycles imposed by the abrasive particles until a local fracture occurs at the material surface. At a low sliding velocity, a correlation was observed between 1/f and the low stress fatigue life. At a high sliding velocity, f approached unity and a correlation was found between the wear rate and the tensile fracture work, which is in agreement with the Ratner–Lancaster plot.
- **Richard Waudby, GwidonStachowiak , MarcinWolski , PawelPodsiadlo , Mark Gee , John Nunn , CarstenGachot , Lawrence L** In this work the effect of surface roughness and topographical orientation on friction and wear has been investigated for diamond like carbon (DLC) coated and uncoated steel surfaces with three levels of surface roughness in the range of 0.004–0.11 μmRa value and with topographical orientations at 0°, 45° and 90° angles from grinding marks. In this first part we report the experimental observations that form the basis for future computational modelling of the tribological effects and mechanisms. The surfaces were characterised by the scanning electron microscopy (SEM) and focused ion beam (FIB) method and mechanical properties were measured. In the topographical characterisation measurements included the fractal signatures, the texture aspect ratio signatures and the texture direction signatures were measured and calculated by the variance orientation transform (VOT) method. The friction and wear were measured and observed in scratch testing, micro tribological testing and linear reciprocating testing in three directions of topographical orientation, as well as in rotational pin-on-disc testing. The topographical orientation had considerable effect on both friction and wear in DLC vs DLC contacts while the effect was minor and sometimes not even observable in steel vs steel contacts. A surface strengthening effect which is higher for smooth DLC surfaces and micro- cracking and micro-delamination on asperity tips at low loads for rougher surfaces is reported. The 45° orientation resulted in higher friction and considerably higher ball wear in linear reciprocating pin-on-plate testing of DLC surfaces compared with the 0° and 90° orientations.
- **E. Falconnet , J. Chambert, H. Makich , G. Monteil** This work presents a combination of finite

element simulations of copper alloy thin sheet blanking and a wear algorithm based on Archard formulation for abrasive wear of the punch. Firstly, a tribometer has been specifically designed to measure wear coefficient, and punch worn profiles have been extracted by means of a double-print method. Secondly, the blanking process has been simulated through the finite element method by using an elasto-plastic constitutive model and the shear failure model. Thirdly, a wear algorithm has been programmed using experimental wear data and mechanical fields computed from blanking simulation. Then, a damage criterion, namely the shear failure model, has been calibrated by an original method based on stress triaxiality analysis and shear height value measured from blanked edge profile. Finally, punch wear predictions have been discussed and compared to experimental results.

- **F.L. Miguel, R. Müller , A. Rosenkranz , S. Mathur ,F. Mücklich** The work here described aimed to assess the tribologicalbehaviour of a Ni- matrix-nanocomposite film and to gain understanding of the role that the reinforcing phases play in it. The composite consisted of an array of Ag-coated SnO2 nanowires grown onto a substrate, around which the Ni matrix was galvanostatically deposited. Friction and wear were Organopolysiloxaneluated under dry sliding conditions using a linearly reciprocating ball-on-flat setup, with a diamond ball of 5.8 µm radius as counterbody, subjected to loads ranging from 5 to 30 mN. The surface and cross section of the wear tracks were characterised by scanning electron microscopy, energy-dispersive X-ray spectroscopy and white light interferometry. Ploughing-type abrasive wear was observed, with load-dependent dynamic friction coefficients, being this attributed to scale effect. Numerical models were developed for the analysis of wear volume and wear rate, as function of film hardness, applied load and wear track length. Due to their higher hardness, the composite films exhibited superior wear resistance with respect to Ni films produced using the exact same bath and deposition parameters as the composite′s matrix. This was evidenced by reductions of up to 74 and 65% in wear volume and rate, respectively.
- **S. Hernandez , J. Hardell , H. Winkelmann , M. Rodriguez Ripoll , B. Prakash** In many industrial applications the occurrence of abrasive wear results in failure and replacement of components. Examples of these applications are found in mining, mineral handling, agriculture, forestry, process and metalworking industry. Some of these

applications also involve operation of relatively moving surfaces at elOrganopolysiloxaneted temperatures which increases the severity of wear. A typical example of high temperature wear phenomena is that of tool steels during interaction with boron steel in hot forming. Some studies have been carried out regarding the high temperature tribological behavior of these materials but results pertaining to their high temperature three body abrasive behavior have not been published in the open literature. In this work, the high- temperature three body abrasive wear behavior of boron steel and two different prehardened tool steels (Toolox33 and Toolox44) was investigated using a high temperature continuous abrasion machine (HT-CAT) at different temperatures ranging from 20 °C to 800 °C using a load of 45 N and a sliding speed of 1 ms−1. The wear results were correlated to the hot hardness of the different materials measured by means of a hot hardness tester (HHT) at a load of 10 kgf. Scanning electron microscopy and energy dispersive spectroscopy (SEM/EDS) techniques were used to characterise the worn surfaces. The hot hardness measurements of the three different materials showed a slight but continuous decrease of hardness from room temperature to 600 °C. At temperatures above 600 °C the hardness showed a sharp decrease. The wear rate of Toolox44 was constant from 20 °C to 400 °C. On the other hand, Toolox33 and boron steel, showed a reduced wear rate from 20 °C to 400 °C attributed to an increased toughness and the formation of wear-protective tribolayers respectively. At higher temperatures (from 400 °C to 800 °C), the wear rate for these materials increased mainly due to a decrease in hardness and the occurrence of recrystallization processes.

CHAPTER-3

PROBLEM FORMULATION

3.1 Need of Present Work

On the basis of literature review it has been observed that the wear studies were conducted on wide varieties of materials/alloys. It has been observed that there is no review work on Organopolysiloxane. The present study is based on Abrasive wear behavior of Organopolysiloxane. A systematic study of abrasive were of Organopolysiloxane has been carried out using a two body pin-on-disc wear machine. In this thesis a study of abrasive wear of Organopolysiloxane at different speed were given to analyze the possibility of wear. Mainly focus on the varying wear condition during varying RPM.

3.2 Objectives of the Present Work

The aim of present work is to check the abrasive wear of abrasive of Organopolysiloxane at same orientation of the specimen but different applied loads.

In this connection the following procedure were aimed to be carried out.

- To fabricate single orientation pin on disc setup.
- To select same materials for the desired test at different weight.
- To study the abrasive wear characteristics of the selected materials of the specimen.
- To determine the abrasive wear characteristics at different applied loads.
- To determine the abrasive wear characteristics at different applied RPM.

CHAPTER -4

MATERIALS AND METHODOLGY

4.1 Experimentation

In this chapter, details of material used in the present investigation and its preparation has been described and the details of the experimentation on wear studies in the material of present investigation have been given.

In order to carry out the experimental work, the procedure is as follows.

(i) Fabrication of Test Rig
(ii) Specimen‘s Materials
(iii) Wear characterization

4.2 Fabrication of Test Rig

Numerous researches have been done in the field of abrasive wear. This work is also an experimental design in the field of abrasive wear Organopolysiloxaneluation via a newly designed wear test rig. In view of the objective a set-up was needed to be designed which can calculate wear rate at different speed (rpm) of work piece with respect to the main frame (horizontal position).

The wear machine used for Organopolysiloxaneluating wear properties was designed by **Prof. (Dr.) Zahir Hasan** and fabricated by **Dr. Mohd Shadab Khan.** A pin on disc wear test technique was adopted to test the wear behavior of specimens.

Wear rate and wear mass were Organopolysiloxaneluated at different orientation of the specimen. The tests were conducted for seven different orientations namely **100 rpm , 150 rpm, 200 rpm .** The wear mass of above said specimen Organopolysiloxaneluated at a constant time of **2min (120 sec).**

The set-up has following different parts-:

(1)Controller (2)D.C Motor (3)Flange Coupling (4)Bearing (5)Main Frame (6)Frame(Angular) (7)Acrylic Sheet (8) Grinding Wheel (9) Specimen (10) Screw Jack (11) Load Cell (12) Angular Lever.

The designed setup is shown in the fig. 4.1 and 4.2

4.3 Experimental Setup of Wear Test Rig

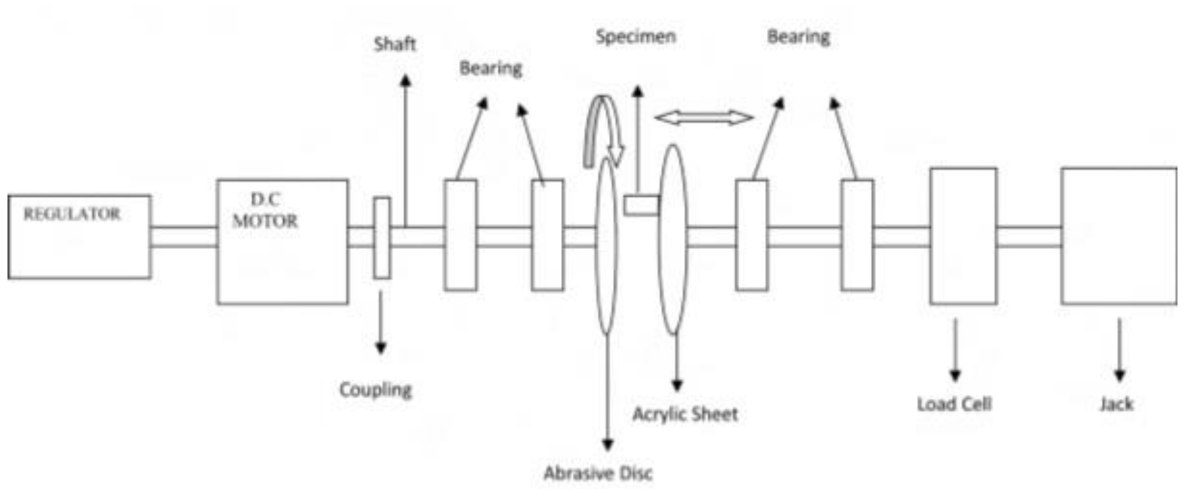


Fig- 4.1 Experimental Setup (Front View)

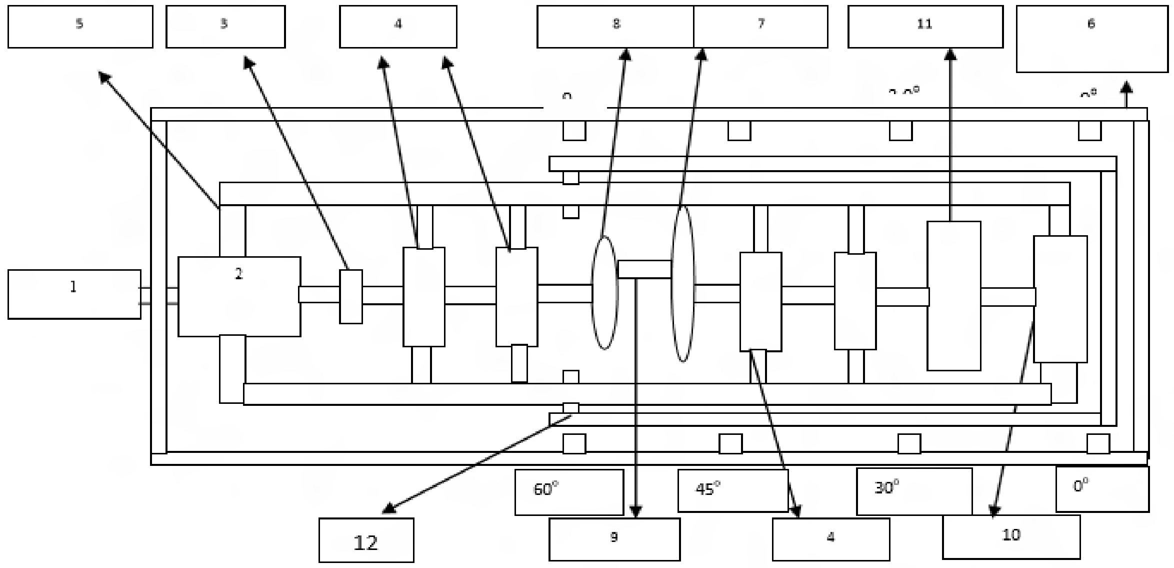


Fig- 4.1 Experimental Setup (Top View)

4.4 Working of Set-Up

DC motor is connected to regulator through a suitable electrical wiring. Further, flange coupling connects D.C motor to a shaft. A key is provided for connecting DC motor and shaft. Grinding disc is connected to one end of the shaft which is supported by two bearings. The specimen is fitted in specimen holder. The specimen holder is made of wood; a slot equal to the size of cross- section of specimen is made in it, to properly hold the same. The samples are fastened with the fixture in these slots, one at a time and the wear test is performed. The fixture is fitted in acrylic sheet having multiple holes along the radius of the sheet. These holes are made in such a way to get fresh surface along grinding disc. At the end of the acrylic sheet there is attachment to apply a load. The load is applied with help of screw jack, as the screw jack moves forward it pushes the acrylic sheet with help of shaft which connects screw jack and acrylic sheet. The whole arrangement of attachment, different parts and assemblies is discussed and shown in the figures later in chapter.

4.5 Description of the Parts of the Wear Test Rig

4.5.1 DC Motor

The D.C. Motor having following specifications:

Power – 1 H.P, Rotation – 1 rpm to 3000 rpm

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: o.4 ampere
The technical parameters of Voltmeter are: Voltage Range : o – 300V , Least Count: 20 V

4.5.2 Frame

The main frame is just like chassis to the engine ,it hold all the parts such as motor , shaft , coupling , screw jack and all its related attachment. 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

4.5.3 Acrylic Disc

The acrylic disc is used as a fixture of specimen holder. The disc is drilled with multiple holes at different radius. This is done so that every specimen gets fresh abrasive surface. This makes synchronization in the calculation of wear rate of the entire specimen. The dimensions of the acrylic disc are as follows:

Diameter – 26 cm

Radius of the first hole (r1) = 8 cm Radius of the second hole (r2) = 16 cm Radius of the third hole (r3) = 24 cm

4.5.4 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 cm

4.5.5 Speed Of Grinding Wheel

Generally all the abrasive processes are performed with the wheel speed in between the range of 300 to 2000 rpm with the maximum work speed from 0 to 60 m/min.

4.5.6 Shaft

Two shafts were used , the first shaft connects motor to the abrasive disc and second shaft connects accrylic disc to screw jack. Load is applied with help of second shaft , it pushes the specimen against the rotating abrasive disc.

The dimensions of the shaft are as follows :

Diameter – 25mm Length (First) – 20 cm Length (Second) – 30 cm

4.5.7 Screw Jack

The screw jack is used to apply the load gradually turn wise. The screw jack is connected to the shaft, which is further connected to the acrylic disc and specimen fixture.As the screw jack unfolds, it pushes the shaft and acrylic sheet which holds the specimen against the abrasive disc.

4.5.8 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 Max. Capacity – 5 Kg

4.6 Diagram of Experimental Setup

Fig-4.2 Experimental Setup –With Controller

Fig-4.3 Experimental setup (Front View)

Fig-4.4 Experimental set up (Top View)

Fig-4.5 Experimental set up (Close View)

Fig-4.6 Specimen

Fig-4.7 Regulating control system to set RPM

Fig-4.8 Experiment performed on setup

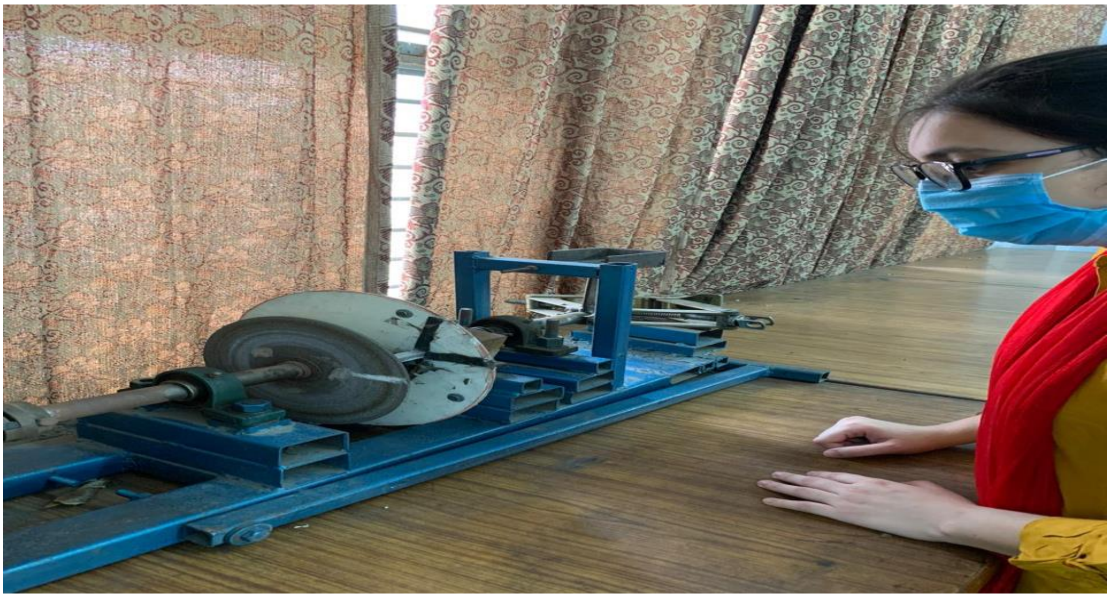


Fig-4.9 Working procedure

Fig-4.10 Stroboscope to measure RPM

4.7 Specimen's Materials

The organopolysiloxane composition proposed is a blend of a conventional diorganopolysiloxane or a dimethylpolysiloxane oil and a limited amount of an (etherified) perfluoroalkyl group-containing organopolysiloxane such as those represented by the group of 1 to 14 carbon atoms or an etherified perfluoroalkyl group of 2 to 14 carbon atoms having at least one oxygen atom between two carbon atoms forming an ether linkage, R is a hydrogen atom or a monovalent hydrocarbon group having 1 to 10 carbon atoms, Y is a divalent organic group having 2 to 5 carbon atoms, the subscripts a and b are, each independently from the other, zero or a positive integer and the subscripts c and d are, each independently from the other, zero, 1, 2 or 3 with the proviso that at least one of the subscripts a, c and d is not zero. By virtue of the admixture of this unique adjuvant, the silicone oil composition can be imparted with greatly increased spreadability even on the surface of a fluorocarbon resin film although the surface tension of the oil is not remarkably decreased thereby.

4.8 Selection of Applied Load

In view of the problem formulated, it is important to select such a load on the specimen which can withstand the pressure applied on grinding disc as well as the load taken by D. C. motor in rotating the grinding disc. Since D. C. motor used in the setup is of 1 H.P. The applied loads selected are in synch with the same. Thus for wear studies the following loads are the options.

i. 5N
ii. 10N
iii. 15N

4.9 Test Procedure

The test stated for each specimen of the material in order viz Silicon ORGANOPOLYSILOXANE. Before each test, the weight of the specimen was taken carefully using an Electronic balance with an accuracy of **0.001g**. After a travel time of **02 minutes** against the grinding disc, the sample was taken out carefully from the fixture. The debris‘s were removed from the valleys of the specimen with the help of cotton cloth so that the exact wear of materials can be measured. Once again the weight of the grinded test specimen was taken carefully using the above electronic balance and the difference in weight was noted.

This was continued for different times at different specimens. For every specimen there‘s a change in rpm but at different load and wear test was conducted using same procedure as discussed above. The effect of weight loss was taken for calculating the wear mass and wear rate.

CHAPTER-5

RESULTS, CONCLUSION AND FUTURE SCOPE

The test procedure started by making 9 sets of Organopolysiloxane carrying 5 different specimen in each set. The results on weight loss have been presented as a function of sliding distance against grinding Disc. The wear rate has been Organopolysiloxaneluated in term of weight loss in the entire specimen investigated. The effect of load and speed (rpm) on the wear rate has been discussed. In addition, the effect of abrasive size on wear rate of fibers has also been discussed. All the calculations is investigated by weighting the specimen before grinding and after grinding and then the loss of weight after abrasion is considered as the wear rate. The wear rate increases gradually at different rpm.

5.1 Effect of Speed (rpm) On Abrasive Wear of Organopolysiloxane at Constant Load

As the wear studies were conducted against the abrasive media (grinding disc). The selection of applied load and the position of the specimen for wear studies were taken as three different loads. Five reading of wear were taken from three sets at different rpm. The result shows that as the speed (rpm) increases the wear rate of the specimen increases for a same load.

The tests for wear rate are held at 3 sets of specimen at different rpm but at a constant applied load . These tests are done at

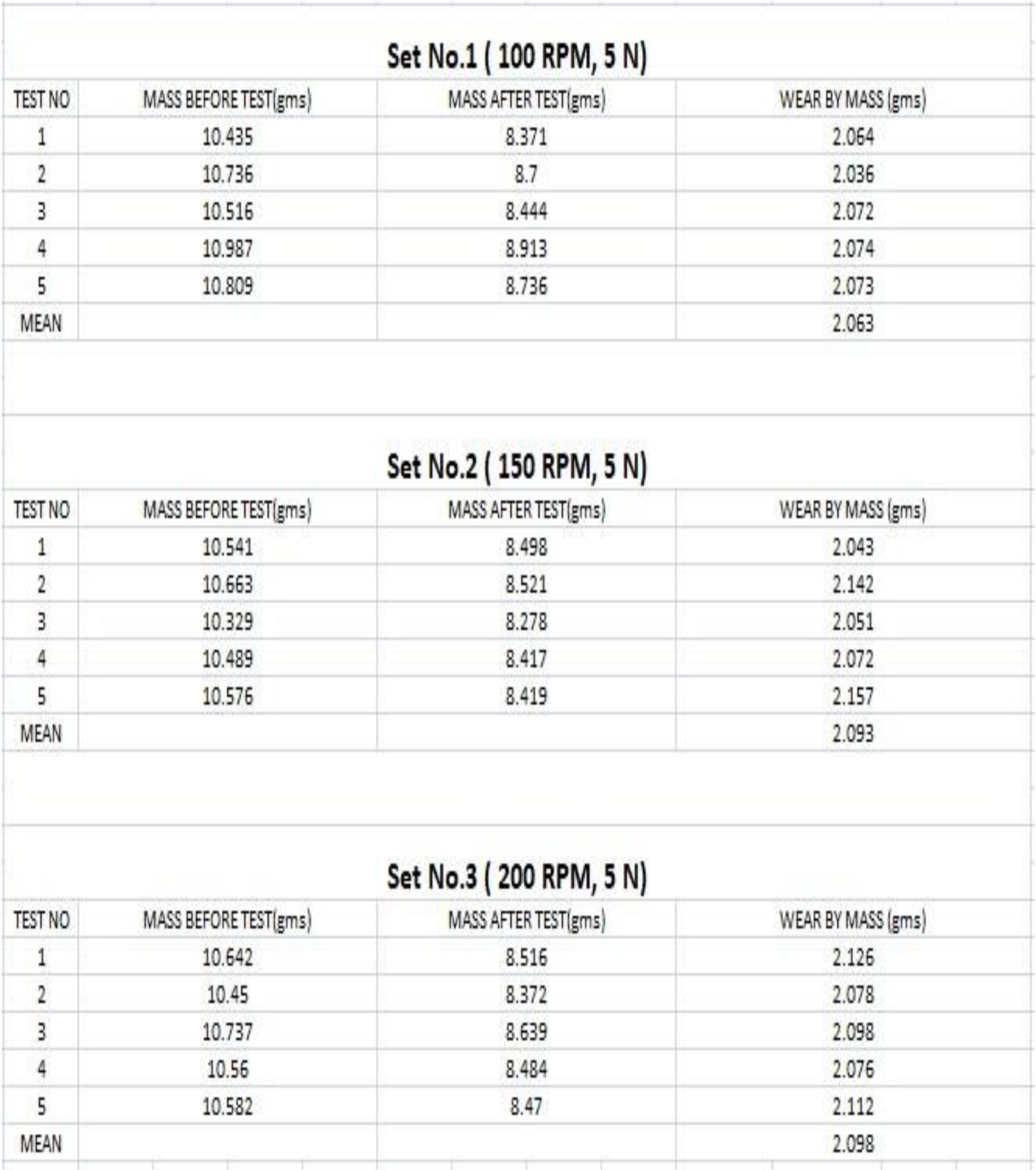
i. 100RPM
ii. 150RPM
iii. 200RPM

Observation Table

Following test results have been observed during investigation of wear behavior of Organopolysiloxane different sets at different angular speed and different applied load.

- Applied load = 5 N

  Time = 2 minute



Set No.1 (100 RPM, 5 N)

TEST NO	MASS BEFORE TEST(gms)	MASS AFTER TEST(gms)	WEAR BY MASS (gms)
1	10.435	8.371	2.064
2	10.736	8.7	2.036
3	10.516	8.444	2.072
4	10.987	8.913	2.074
5	10.809	8.736	2.073
MEAN			2.063

Set No.2 (150 RPM, 5 N)

TEST NO	MASS BEFORE TEST(gms)	MASS AFTER TEST(gms)	WEAR BY MASS (gms)
1	10.541	8.498	2.043
2	10.663	8.521	2.142
3	10.329	8.278	2.051
4	10.489	8.417	2.072
5	10.576	8.419	2.157
MEAN			2.093

Set No.3 (200 RPM, 5 N)

TEST NO	MASS BEFORE TEST(gms)	MASS AFTER TEST(gms)	WEAR BY MASS (gms)
1	10.642	8.516	2.126
2	10.45	8.372	2.078
3	10.737	8.639	2.098
4	10.56	8.484	2.076
5	10.582	8.47	2.112
MEAN			2.098

- Applied load = 10 N

  Time = 2 minute

Set No.4 (100 RPM, 10 N)

TEST NO	MASS BEFORE TEST(gms)	MASS AFTER TEST(gms)	WEAR BY MASS (gms)
1	10.651	8.534	2.117
2	10.569	8.504	2.065
3	10.362	8.231	2.131
4	10.956	8.817	2.139
5	10.762	8.628	2.134
MEAN			2.117

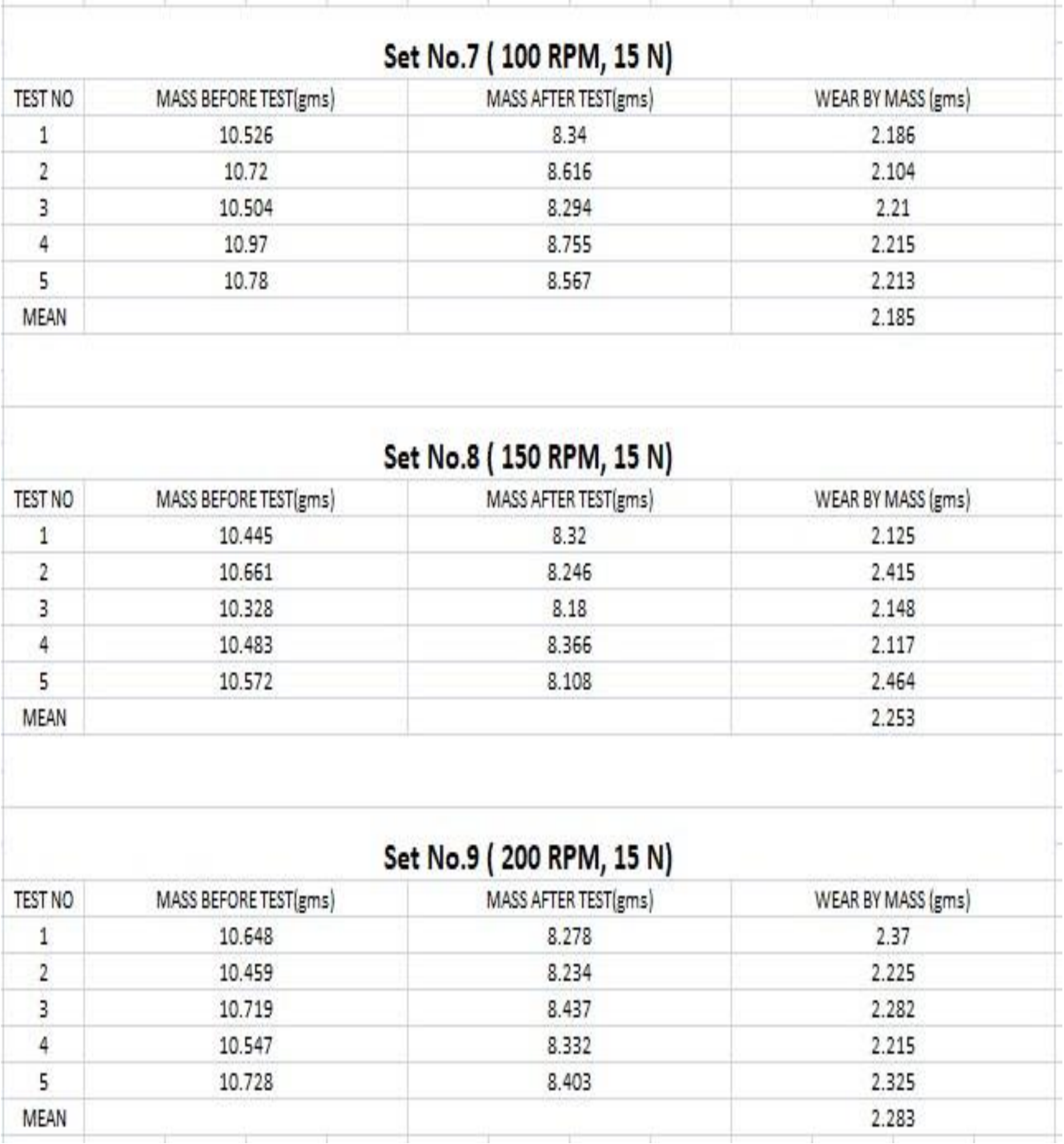
Set No.5 (150 RPM, 10 N)

TEST NO	MASS BEFORE TEST(gms)	MASS AFTER TEST(gms)	WEAR BY MASS (gms)
1	10.486	8.409	2.077
2	10.078	8.815	2.263
3	10.446	8.352	2.094
4	10.39	8.253	2.137
5	10.442	8.143	2.299
MEAN			2.174

Set No.6 (200 RPM, 10 N)

TEST NO	MASS BEFORE TEST(gms)	MASS AFTER TEST(gms)	WEAR BY MASS (gms)
1	10.516	8.271	2.245
2	10.486	8.339	2.15
3	10.45	8.263	2.187
4	10.987	8.842	2.145
5	10.541	8.327	2.214
MEAN			2.188

- Applied load = 15 N
  Time = 2 minute



Set No.7 (100 RPM, 15 N)

TEST NO	MASS BEFORE TEST(gms)	MASS AFTER TEST(gms)	WEAR BY MASS (gms)
1	10.526	8.34	2.186
2	10.72	8.616	2.104
3	10.504	8.294	2.21
4	10.97	8.755	2.215
5	10.78	8.567	2.213
MEAN			2.185

Set No.8 (150 RPM, 15 N)

TEST NO	MASS BEFORE TEST(gms)	MASS AFTER TEST(gms)	WEAR BY MASS (gms)
1	10.445	8.32	2.125
2	10.661	8.246	2.415
3	10.328	8.18	2.148
4	10.483	8.366	2.117
5	10.572	8.108	2.464
MEAN			2.253

Set No.9 (200 RPM, 15 N)

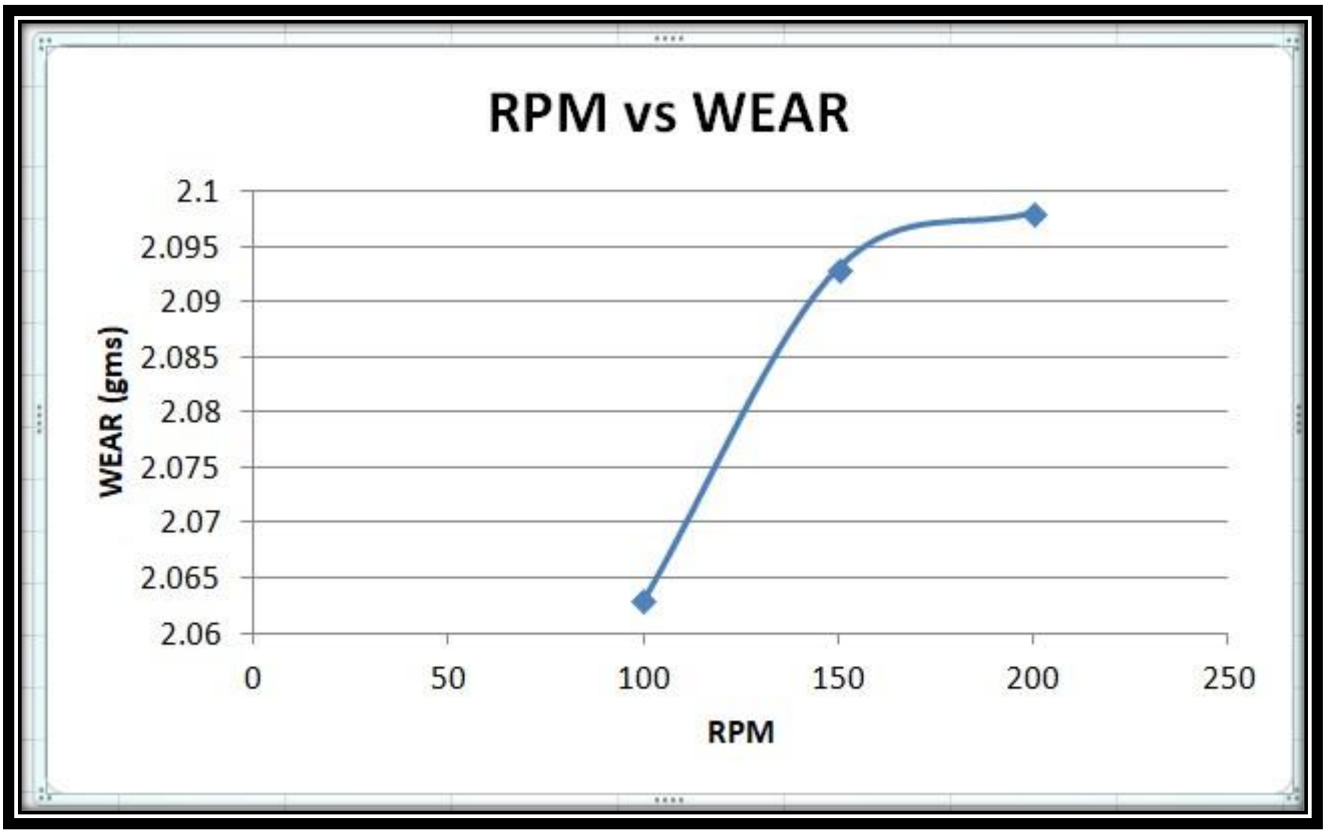
TEST NO	MASS BEFORE TEST(gms)	MASS AFTER TEST(gms)	WEAR BY MASS (gms)
1	10.648	8.278	2.37
2	10.459	8.234	2.225
3	10.719	8.437	2.282
4	10.547	8.332	2.215
5	10.728	8.403	2.325
MEAN			2.283

Graphical representation

After conducting total experiment regarding our investigation of abrasive behavior of Silicon ORGANOPOLYSILOXANE polymer
Following mean results has been obtained. These results are shown in tabular form below:

* At 5N- RPM vs. WEAR

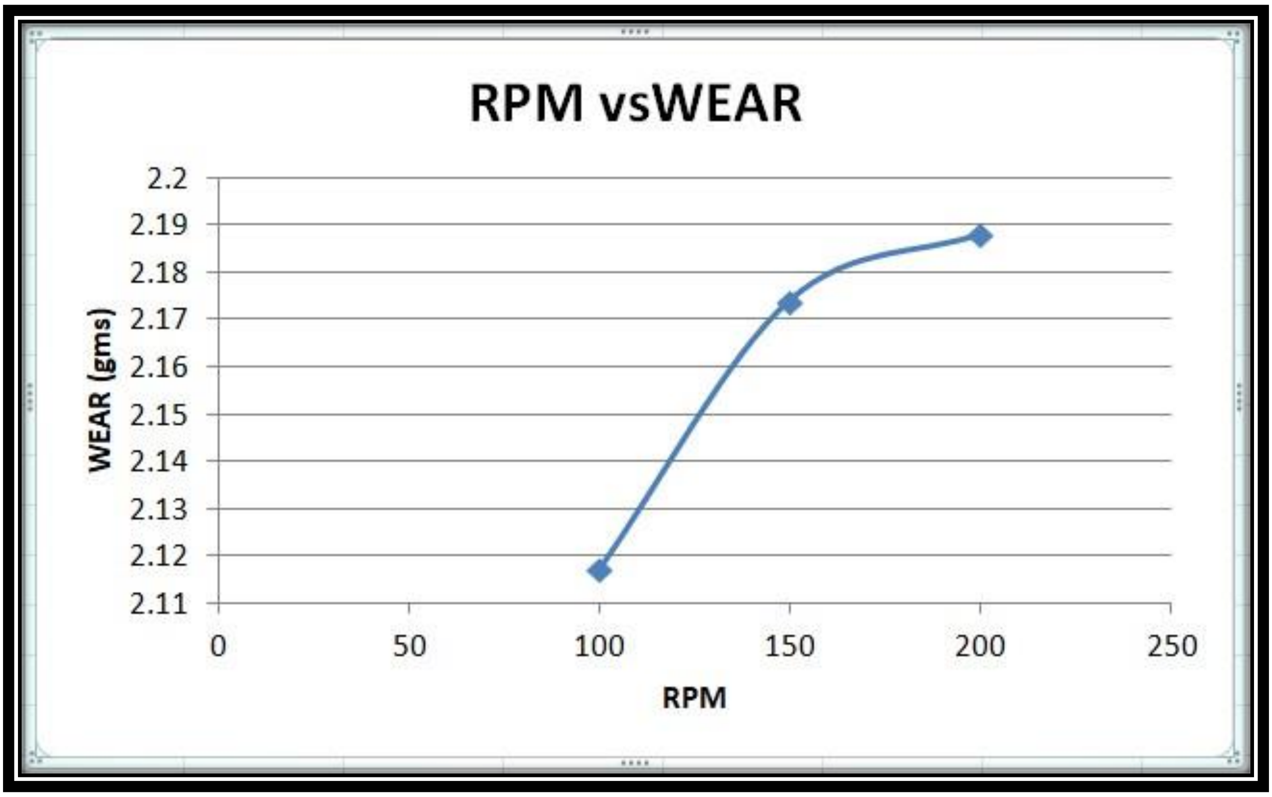
RPM	WEAR (gms)
100	2.063
150	2.093
200	2.098



GRAPH-5.1

*** At 10 N- RPM vs. WEAR**

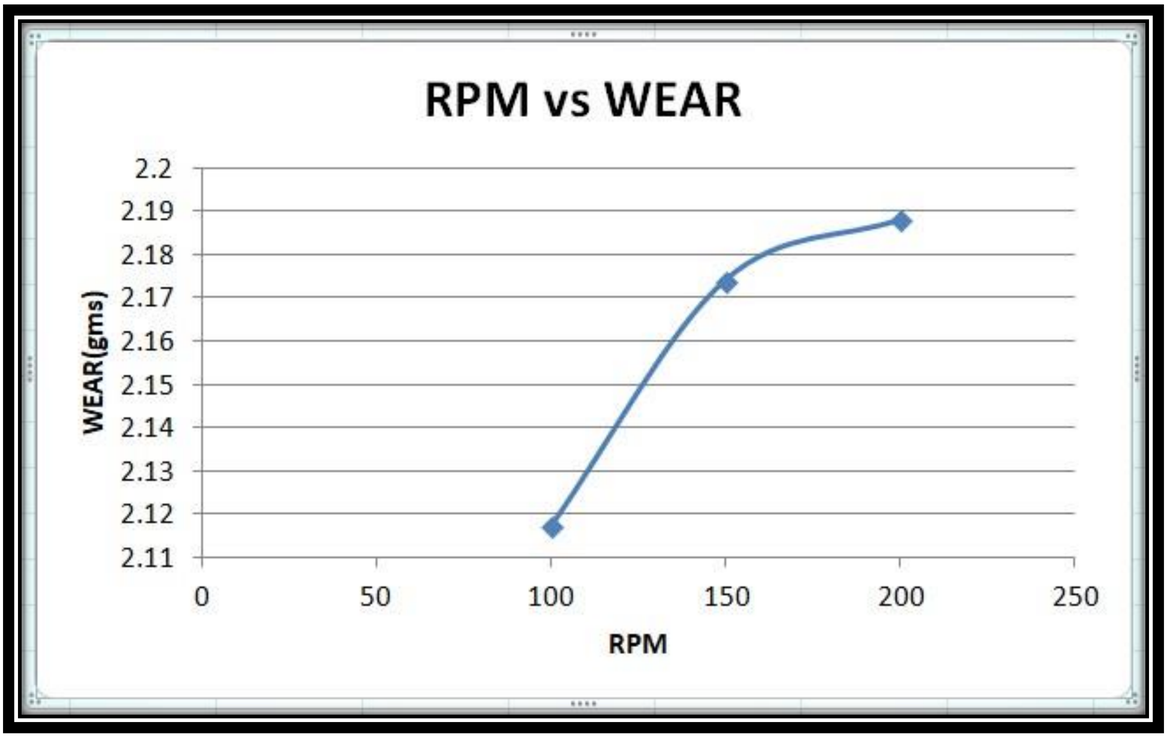
RPM	WEAR (gms)
100	2.117
150	2.174
200	2.188



GRAPH-5.2

*** At 15 N- RPM vs. WEAR**

RPM	WEAR(gms)
100	2.185
150	2.253
200	2.283

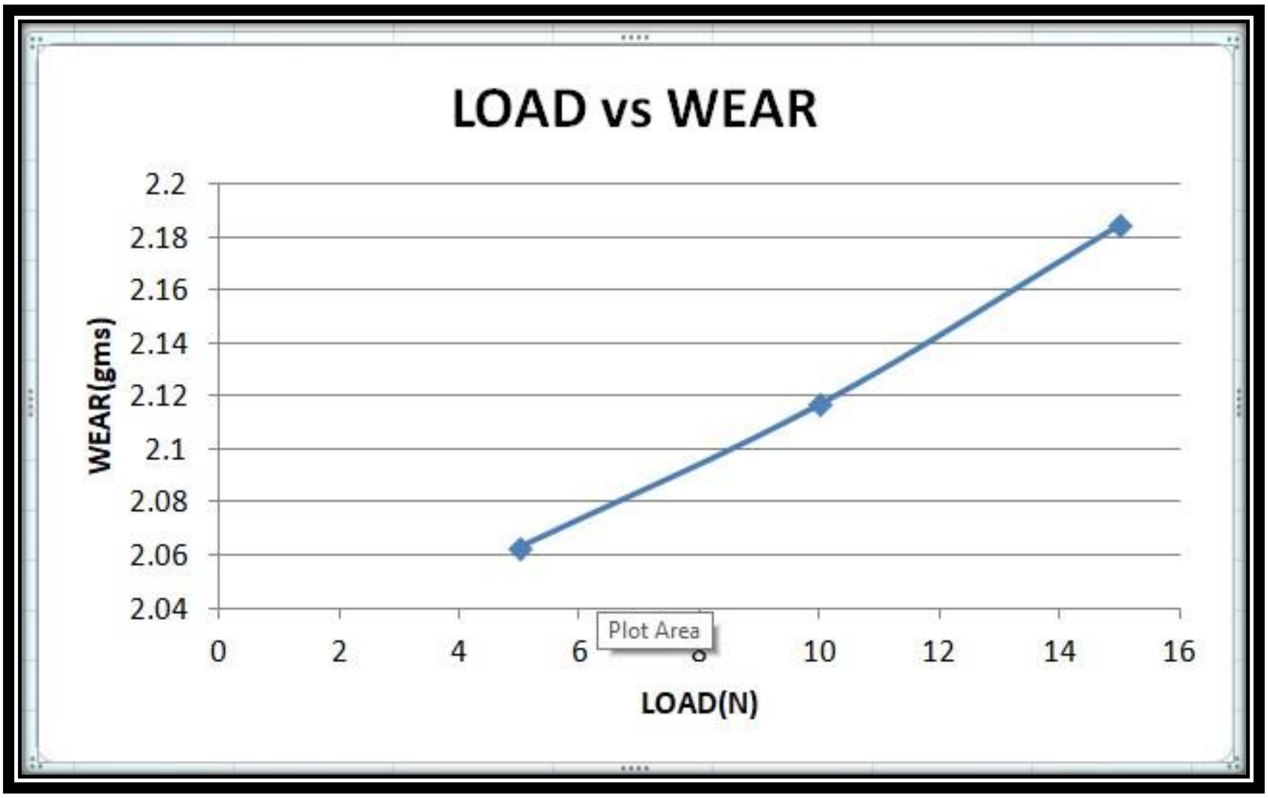


GRAPH-5.3

5.3 Effect of Speed (rpm) On Abrasive Wear of Organopolysiloxane at Constant Angular Speed

- **LOAD vs. WEAR**

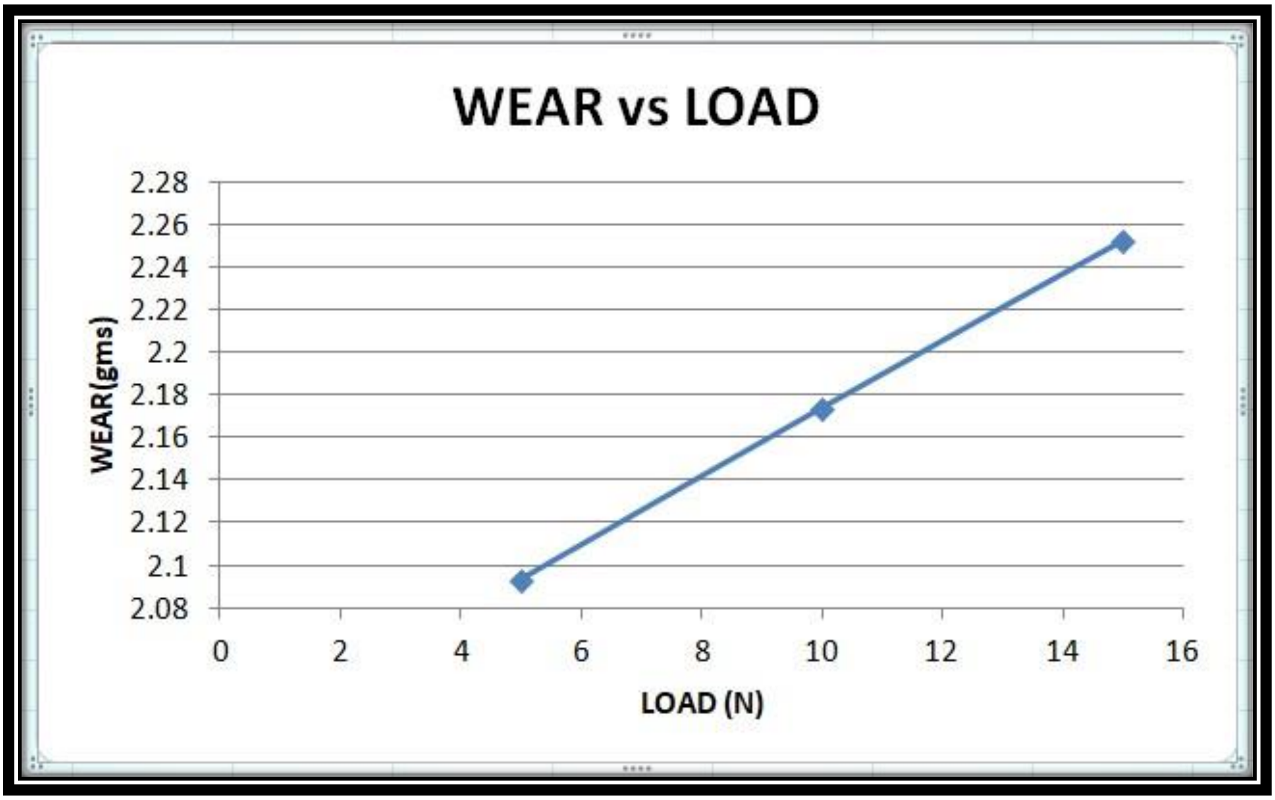
LOAD (N)	WEAR (gms)
5	2.063
10	2.117
15	2.185



GRAPH-5.4

- **LOAD vs. WEAR**

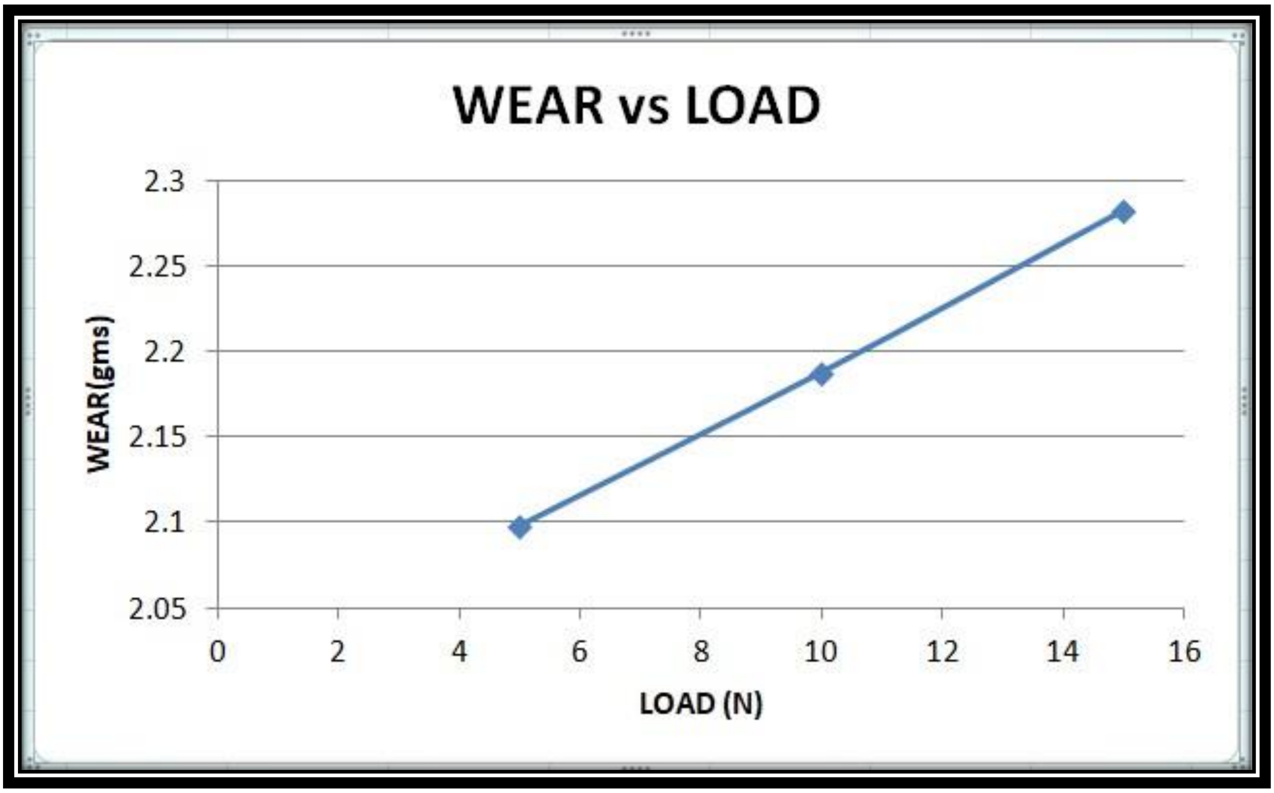
LOAD (N)	WEAR(gms)
5	2.093
10	2.174
15	2.253



GRAPH-5.5

- **LOAD vs. WEAR**

LOAD (N)	WEAR (gms)
5	2.098
10	2.188
15	2.283



GRAPH-5.6

5.4 **DISCUSSION**

The main findings of the investigation have been listed out. The suggestion for the future work have also been indicated. The specimen do not get fresh abrasive surface,due to this wear resistance increases. Following results are discussed below:

GRAPH-5.1

This graph shows RPM vs WEAR at 5 N. The wear loss increases while RPM increases. The graph is not linear in nature.

GRAPH-5.2

This graph shows RPM vs WEAR at 10 N. The wear loss increases while RPM increases. The graph is not linear in nature.

GRAPH-5.3

This graph shows RPM vs WEAR at 15 N. The wear loss increases while RPM increases. The graph is not linear in nature. In this graph wear loss is more as compare to graph 1 and graph 2.

GRAPH-5.4

This graph shows LOAD vs WEAR at 5 N. The wear loss increases while load increases. The graph is linear in nature , this shows linear relationship between load and wear.

GRAPH-5.5

This graph shows LOAD vs WEAR at 10 N. The wear loss increases while load increases. The graph is linear in nature , this shows linear relationship between load and wear.

GRAPH-5.6

This graph shows LOAD vs WEAR at 15 N. The wear loss increases while load increases. The graph is linear in nature , this shows linear relationship between load and wear. In this graph wear loss is more as compare to graph 1 and graph 2.

5.5-CONCLUSION

It is concluded from the above discussion that wear is function of applied load. Initially, it was understood that wear depends upon applied load, surface parameters and mechanical properties such as hardness, toughness etc.

Thus it can be concluded that:

- There is a linear relationship between wear and load
- The wear loss increases while load increases. Wear loss is more at 15 N load as compare to 5 N and 10 N load.
- The wear loss increases while RPM increases.
- The wear loss in first minute is more as compare to last minute while increasing the RPM

5.6 FUTURE SCOPE

As discussed in problem formulation, the said experiments were conducted just to check the idea.

The experimental work has been completed with selected material randomly viz, Organopolysiloxane. These experiments can also be conducted on other materials and composites. The work is not limited to a particular set of orientations, it can also be Organopolysiloxaneluated at other orientations and synchronize the results which can further enhance the applicability of wear equation. In the present work only loads less than 15N have been selected, the load can be increased above 15N and variation in wear can be Organopolysiloxaneluated.

CHAPTER-6

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