STUDY OF WEAR BEHAVIOUR OF RICE HUSK CERAMIC COMPOSITES

A THESIS SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelors of Technology

in

Mechanical Engineering

By

RABISHANKAR BISWAL

Department of Mechanical Engineering

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Under the Guidance of

Prof. S. K. ACHARYA

Department of Mechanical Engineering

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CERTIFICATE

This is to certify that thesis entitled, "**STUDY OF WEAR BEHAVIOUR OF RICE HUSK CERAMIC COMPOSITES**" submitted by Mr. RABISHANKAR BISWAL in partial fulfillment of the requirements for the award of Bachelors of Technology Degree in Mechanical Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other university/ institute for award of any Degree or Diploma.

Date:

Prof. S.K.Acharya
Dept. of Mechanical Engineering
National Institute of Technology
Rourkela-769008

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Date: **RABISHANKAR BISWAL**

ROLL NO.-10603064

ABSTRACT

In recent years composites have attracted substantial importance as a potential structural material. The most basic & common attractive features composites that make them useful for industrial applications are low cost, light weights, high specific modulus, renewability and biodegradability. Rice Husk ceramics composites are an important area of interest these days for development of new composite materials. These composites are gaining importance due to their non-carcinogenic and bio-degradable nature. Rice Husk contains about 20% ash, 22% lignin, 38% cellulose, 18% pentosans, 2% moisture. But once the husk is carburized in Nitrogen atmosphere it forms Rice Husk ash. This ash contains 95% silica (SiO_2), 1% K_2O, 1% CaO, P_2O_5 & Na_2O_3, Fe_2O_3 & MgO. The silica in rice husk exists in the amorphous form but became crystalline during combustion of the rice husk. The ash as standalone is very useful in making insulation products, refractory materials, Portland cement, masonry cement & pottery products. Now the scope of its usage is also extended to paints & fertilizers. It increases abrasion characteristics & hence finds application in aluminum industries.

Keeping this in view the present research work has been under taken with an objective to explore the use of rice husk ash as potential filler in polymer composite and to study its wear behavior. To study the wear properties the components made from these rice husk ceramics is subjected to wear test using a Pin-on-Disc apparatus. Experiments have been conducted under laboratory conditions to asses the wear behaviour of the rice husk ceramic composites in polymer matrix. The change in weight is studied for a single velocity & various loads applied to composites which vary in the percentage of filler & percentage of matrix. The final result is drawn from the wear test. The conclusion helps us to predict the wear behavior various constituents of rice husk ceramic composites under varying loads & a fixed speed.

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1.1   BACKGROUND

India endowed with an abundant availability of natural fiber such as Jute, Coir, Sisal, Pineapple, Ramie, Bamboo, Banana etc. has focused on the development of natural fiber composites primarily to explore value-added application avenues. Such natural fiber composites are well suited as wood substitutes in the housing and construction sector. The development of natural fiber composites in India is based on two pronged strategy of preventing depletion of forest resources as well as ensuring good economic returns for the cultivation of natural fibers.

The developments in composite material after meeting the challenges of aerospace industry have cascaded down for catering to domestic and industrial applications. Composites, the wonder material with light-weight; high strength-to-weight ratio and stiffness properties have come a long way in replacing the conventional materials like metals, wood etc. The material scientists all over the world focused their attention on natural composites to cut down the cost of raw materials.

1.2   WHY A COMPOSITE?

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. They are usually optimized to achieve a particular balance of properties for a given range of applications.

While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. It is obvious, especially for composites, that the improvement in manufacturing technology alone is not enough to overcome the cost hurdle. It is essential that there be an integrated effort in design, material, process, tooling, quality assurance, manufacturing, and even program management for composites to be competitive with metals.

The composites industry has recognized that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years.

Increasingly enabled by the introduction of newer polymer resin matrix materials and high performance reinforcement fibers of glass, carbon and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. High performance FRP can be found in diverse applications as composite armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. For certain applications, the use of composites rather than metals has resulted in savings of both cost and weight. Some examples are cascades for engines, curved fairing and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands etc.

Further, the need of composite for lighter construction materials and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock & vibration through tailored microstructures. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications. Composites are now extensively being used for rehabilitation/ strengthening of pre-existing structures that have to be retrofitted to make them seismic resistant, or to repair damage caused by seismic activity.

Unlike conventional materials (e.g., steel), the properties of the composite material can be designed considering the structural aspects. The design of a structural component using composites involves both material and structural design. . The improved structural properties generally result from a load-sharing mechanism. It has been found that composites developed for structural applications also provide attractive performance in these other functional areas as well. Composite properties (e.g. stiffness, thermal expansion etc.) can be varied continuously over a broad range of values under the control of the designer. Careful selection of constituent materials i.e. matrix & reinforcement type enables finished product characteristics to be tailored to almost any specific engineering requirement.

Whilst the use of composites will be a clear choice in many instances, material selection will depend on factors such as working lifetime requirements, number of items to be produced (run length), complexity of product shape, possible savings in assembly costs and on the experience & skills the designer in tapping the optimum potential of composites. In some instances, best results may be achieved through the use of composites in conjunction with traditional materials.

1.3   DEFINITION OF COMPOSITE

Given the vast range of materials that may be considered as composites and the broad range of uses for which composite materials may be designed, it is difficult to agree upon a single, simple, and useful definition. The most widely used meaning is the following one, which has been stated by Jartiz [1] "Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form".

The weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its specificity or the laws which should given it which distinguishes it from other very banal, meaningless mixtures.

Kelly [2] very clearly stresses that the composites should not be regarded simple as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them.

Beghezan [3] defines as "The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings", in order to obtain improved materials.

Van Suchetclan [4] explains composite materials as heterogeneous materials consisting of two or more solid phases, which are in intimate contact with each other on a

microscopic scale. They can be also considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property.

1.4 CHARACTERISTICS OF THE COMPOSITES

Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the 'reinforcement' or 'reinforcing material', whereas the continuous phase is termed as the ' matrix'.

Properties of composites dependent on the properties of their constituent materials, their distribution and the interaction among them. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in improved or better properties. Apart from the nature of the constituent materials, the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a greater extent. The concentration, distribution and orientation of the reinforcement also affect the properties.

The shape of the discontinuous phase (which may by spherical, cylindrical, or rectangular cross-sanctioned prisms or platelets), the size and size distribution (which controls the texture of the material) and volume fraction determine the interfacial area, which plays an important role in determining the extent of interaction between the reinforcement and the matrix.

Concentration, usually measured as volume or weight fraction, determines the contribution of a single constituent to the overall properties of the composites. It is not only the single most important parameter influencing the properties of the composites, but also an easily controllable manufacturing variable used to alter its properties.

1.5 CLASSIFICATION

Composite materials can be classified in different ways [5]. Classification based upon the geometry of a representative unit of the reinforcement is convenient because it is the geometry of the reinforcement that is responsible for the mechanical properties and high performance of the composites. A typical classification is presented in table1.1. The two broad classes of composites are (1) Particulate composites and (2) Fibrous composites.

1.5.1 Particulate Composites

As the name itself indicates, the reinforcement is of particle nature (platelets are also included in this). It may be spherical, cubic, tetragonal, a platelet, or of other regular or irregular shape, but it is approximately or roughly equiaxed or equal in shape. Thus, particulate-reinforced composites include those reinforced by spheres, rods, flakes, and many other shapes of roughly equal axes. In general, particles are not very effective in improving fracture resistance but they enhance the stiffness of the composite to a limited extent. Particle fillers are widely used to improve the properties of matrix materials such as to modify the thermal and electrical conductivities, improve performance at elevated temperatures, reduce friction, increase wear and abrasion resistance, improve machinability, increase surface hardness and reduce shrinkage.

1.5.2 Fibrous composites

A fiber is characterized by its length being much greater compared to its cross-sectional dimensions. The dimensions of the reinforcement determine its capability of contributing its properties to the composite. Fibers are very effective in improving the fracture resistance of the matrix since a reinforcement having a long dimension discourages the growth of incipient cracks normal to the reinforcement that might other wise lead to failure, particularly with brittle matrices.

Man-made filaments or fibers of non polymeric materials exhibit much higher strength along their length since large flaws, which may be present in the bulk material, are minimized because of the small cross-sectional dimensions of the fiber. In the case of polymeric materials, orientation of the molecular structure is responsible for high strength and stiffness.

```
                          ┌─────────────────────────┐
                          │   Composite materials   │
                          └─────────────────────────┘
                    ↓                              ↓
        ┌──────────────────────────┐   ┌───────────────────────────────┐
        │ Fiber reinforced composites│   │ Particle reinforced composites│
        └──────────────────────────┘   └───────────────────────────────┘
```

Composite materials

Fiber reinforced composites

Particle reinforced composites

Single layer composite

Multi layered composites

Random orientation

Preferred orientation

Continuous fiber reinforced

Discontinuous fiber reinforced composites

Laminates

Hybrids

Random orientation

Preferred orientation

Unidirectional reinforcement
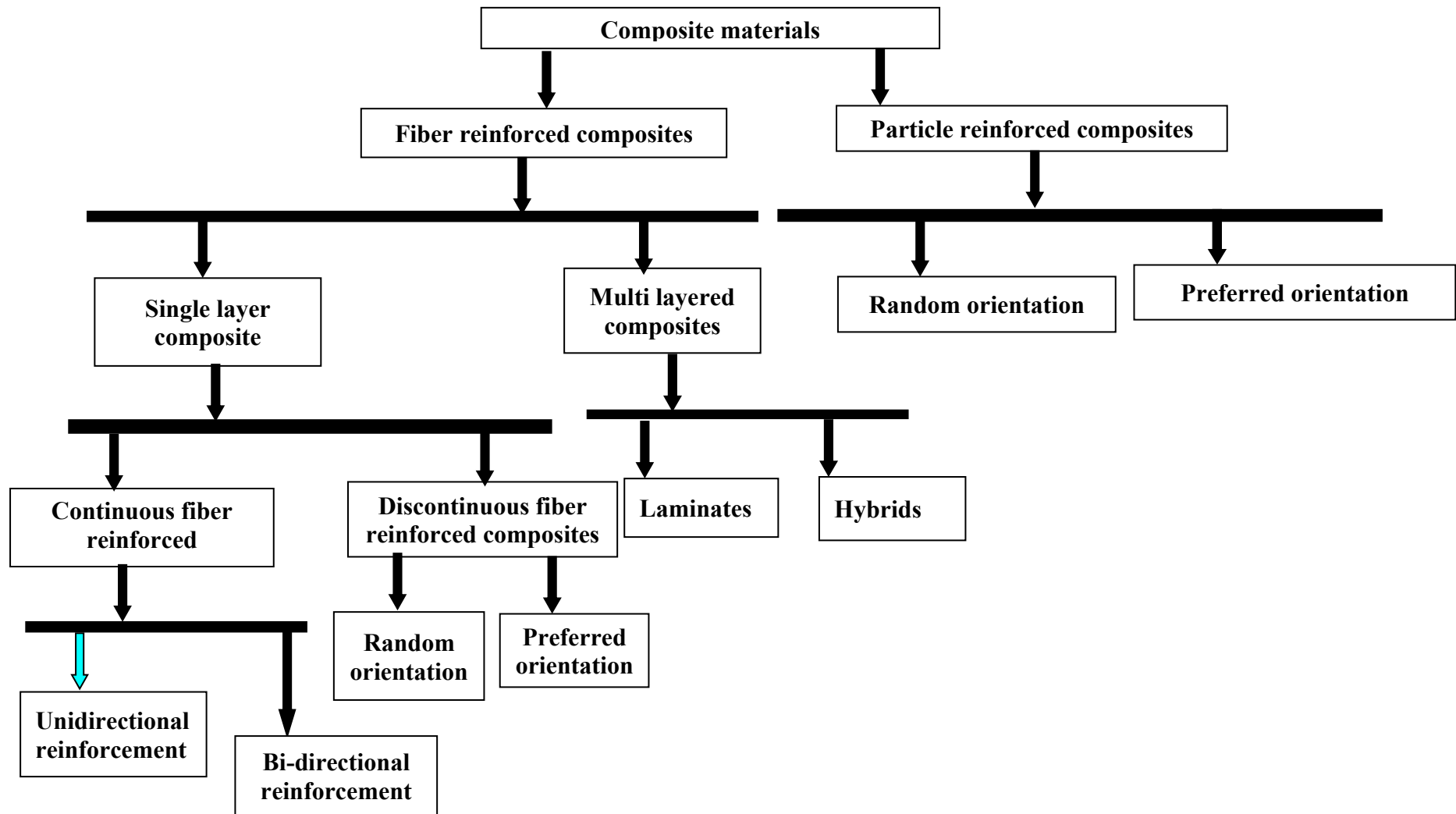
Bi-directional reinforcement

Fig 1 .1   Classification of composites

15

Fibers, because of their small cross- sectional dimensions, are not directly usable in engineering applications. They are, therefore, embedded in matrix materials to form fibrous composites. The matrix serves to bind the fibers together, transfer loads to the fibers, and protect them against environmental attack and damage due to handling. In discontinuous fiber reinforced composites, the load transfer function of the matrix is more critical than in continuous fiber composites.

1.6 COMPONENTS OF A COMPOSITE MATERIAL

In its most basic form a composite material is one, which is composed of at least two elements working together to produce material properties that are different to the properties of those elements on their own. In practice, most composites consist of a bulk material (the 'matrix'), and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix.

1.6.1 Role of matrix in a composite

Many materials when they are in a fibrous form exhibit very good strength property but to achieve these properties the fibers should be bonded to a suitable matrix. The purpose of the matrix is to bind the reinforcements together by virtue of its cohesive and adhesive characteristics, to transfer load to and between reinforcements, and to protect the reinforcements from environments and handling. The matrix also provides a solid form to the composite, which aids handling during manufacture and is typically required in a finished part. The matrix isolates fibers from one another to prevent abrasion and formation of new surface flaws and acts as a bridge to hold the fibers in place. A good matrix should have the ability to deform easily under applied load, transfer the load onto the fibers and evenly distributive stress concentration. Because the reinforcements are typically stronger and stiffer, the matrix is often the "weak link" in the composite, from a structural perspective. As a continuous phase, it controls the transverse properties, inter-laminar strength, and elevated-temperature strength of the composite.

1.6.2 Materials used as matrices in composites

In its most basic form a composite material is one, which is composed of at least two elements working together to produce material properties that are different to the properties

of those elements on their own. In practice, most composites consist of a bulk material (the matrix) and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix.

(a) BULK PHASES

(1) Metal Matrices

Metal matrix composites possess some attractive properties, when compared with organic matrices. These include (i) strength retention at higher temperatures, (ii) higher transverse strength, (iii) better electrical conductivity, (iv) superior thermal conductivity, (v) higher erosion resistance (vi) improvement in low temperature creep (vii) reduction in thermal elongation etc. However, the major disadvantage of metal matrix composites is their higher densities and consequently lower specific mechanical properties compared to polymer matrix composites. Another notable difficulty is the high-energy requirement for fabrication of such composites & sometimes development of magnetic properties.

(2) Polymer Matrices

A very large number of polymeric materials, both thermosetting and thermoplastic, are used as matrix materials for the composites. Some of the major advantages and limitations of resin matrices are shown in Table 1.1.

Table 1.1 Advantages and limitations of polymeric matrix materials

Advantages	Limitations
Low densities	Low transverse strength
Good corrosion resistance	Low operational temperature limits
Low thermal conductivities	
Low electrical conductivities	
Translucence	
Aesthetic Color effects	

Generally speaking, the resinous binders (polymer matrices) are selected on the basis of adhesive strength, fatigue resistance, heat resistance, chemical and moisture resistance etc. The resin must have mechanical strength commensurate with that of the reinforcement. It must be easy to use in the fabrication process selected and also stand up to the service conditions. Apart from these properties, the resin matrix must be capable of wetting and penetrating into the bundles of fibers which provide the reinforcement, replacing the dead air spaces therein and offering those physical characteristics capable of enhancing the performance of fibers.

(3)   Ceramic Matrices

Ceramic fibers, such as alumina and SiC (Silicon Carbide) are advantageous in very high temperature applications, and also where environment attack is an issue. Since ceramics have poor properties in tension and shear, most applications as reinforcement are in the particulate form (e.g. zinc and calcium phosphate). Ceramic Matrix Composites (CMCs) used in very high temperature environments, these materials use a ceramic as the matrix and reinforce it with short fibers, or whiskers such as those made from silicon carbide and boron nitride.

(b)   REINFORCEMENT

The role of the reinforcement in a composite material is fundamentally one of increasing the mechanical properties of the neat resin system e.g. in a continuous fiber-reinforced composite, the fibers provide virtually all of the strength and stiffness. All of the different fibers used in composites have different properties and so affect the properties of the composite in different ways. For most of the applications, the fibers need to be arranged into some form of sheet, known as a fabric, to make handling possible. Different ways for assembling fibers into sheets and the variety of fiber orientations possible to achieve different characteristics.

(c)   INTERFACE

It has characteristics that are not depicted by any of the component in isolation. The interface is a bounding surface or zone where a discontinuity occurs, whether physical, mechanical, chemical etc. The matrix material must "wet" the fiber. Coupling agents are frequently used to improve wet ability. Well "wetted" fibers increase the interface surfaces area. To obtain desirable properties in a composite, the applied load should be effectively transferred

from the matrix to the fibers via the interface. This means that the interface must be large and exhibit strong adhesion between fibers and matrix. Failure at the interface (called debonding) may or may not be desirable.

1.7   TYPES OF COMPOSITE MATERIALS

The composite materials are broadly classified into the following categories as shown in fig 1.2 (a-e).
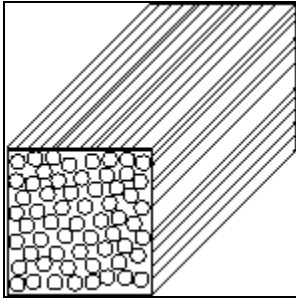
1.7.1   Fiber-Reinforced Composites

Reinforced-composites are popularly being used in many industrial applications because of their inherent high specific strength and stiffness. Due to their excellent structural performance, the composites are gaining potential also in tribological applications. In this type composite the second phase is in the form of fibers dispersed in the matrix which could be either plastic or metal. The volume fraction (V_f) varies from a few percentage to as high as 70%. Usually the fiber reinforcement is done to obtain high strength and high modulus. Hence it is necessary for the fibers to posses' higher modulus than the matrix material, so that the load is transferred to the fiber from the matrix more effectively.

1.7.2   Dispersion Hardened Material

In this type of material, fine particles of sizes ranging from 0.01µm to 0.14µm are dispersed in matrix. Their concentration varies from 1% to 15% by volume. These fine particles impede dislocation movement in the material and therefore result in very high strength. Also these materials posses improved high temperature strength and creep resistance.

1.7.3   Particulate composite

In this type of composites, 1µm to 200µm size particles are dispersed in the matrix and volume fraction is generally between 0.01 V_f to 0.85 V_f.

(a) Random fiber (short fiber) reinforced
composites
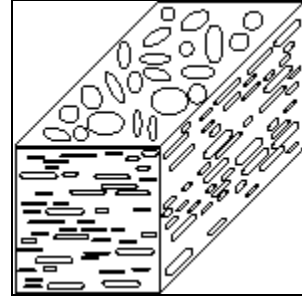
(b) Particles as the reinforcement
(Particulate composites)
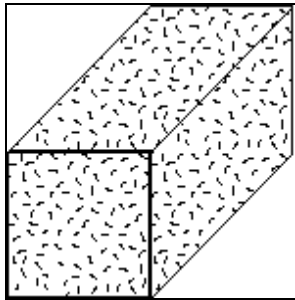
(c) Continuous fiber (long fiber) reinforced
Composites
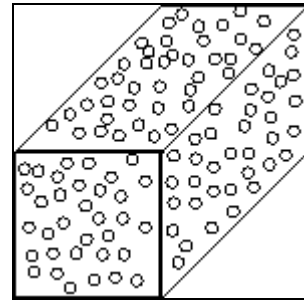
(d) Flat flakes as the reinforcement
(Flake composites)
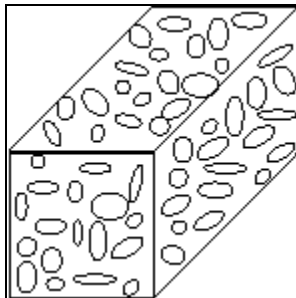
(e) Fillers as the reinforcement (Filler composites)

Fig 1.2 (a-e) Classification of composite materials according to fiber arrangements

1.8   NATURAL FIBER AS FILLER MATERIAL.

Natural fibers are lignocelluloses in nature these composites are gaining significance due to their biodegradable nature. As a matter of fact they are emerging as realistic alternative to glass reinforced composites in many applications. This is because of their low cast, light weight and apparently environmentally superiority in comparison to synthetic fiber. Due these multiple positive characteristics they are finding application in construction & building activities. In addition the most advantage part of these composite is that natural fiber composite is their ease of manufacturing & also they have higher fiber content for equivalent performance, reducing more polluting base polymer content. The light weight natural fiber composites improve fuel efficiency and reduce emission when used in auto applications.

1.9   WEAR

Wear is not an intrinsic property but it depends upon environment variables. These factors include speed, loading cycles of use, temperature, pressure & presence of foreign materials. It may be due to damage caused to the surface or removal to any or both of the exposed surface. In most cases wear causes at the surface when they relative motion. In each case the removal of any material is not the only criteria for the wear to occur, but also any damage to the surface without material removal is also categorized as wear. But in most of the cases it is due to the interaction of surfaces & in many cases it involves transfer of materials between the mating surfaces.

Types of wear: -- Classified by Burwell & Strang [6]

1.) Abrasive (the major cause of wear)

2.) Adhesive

3.) Erosion

4.) Fretting

5.) Chemical

1.) **Abrasive Wear**:--

Abrasive wear can be defined as the kind of wear that occurs when a hard surface slides or contuse to have relative motion with a softer surface. Hard materials or an asperity that

cut groves during this motion produces abrasive wear. These asperities can be those present in the matting surface or any foreign material. This generation of wear fragments hastens the process of wear if not removed.

2.) **Adhesive Wear**:--

Adhesive wear can be defined as the kind of wear that occurs due to localized bonding between the contacting or the mating surfaces. In this kind of wear there is actual transfer of material between the mating surfaces. This transfer depends upon the degree of hardness of the two mating surface. But the precondition for this kind of wear is the intimate contact between the two surfaces. But the application of lubricating surface, oil or grease decreases the tendency of this kind of wear.

3.) **Erosive Wear**:--

This kind of wear is defined as process of metal removal due to impingement of solid particles on a surface. This can also occur due to gas & liquid but the erosion by this medium doesn't carry. There are some specific characteristics of this kind of wear like: -- when the angle of impingement is small, the wear produced is closely analogous to abrasion. When the angle of impingement is normal then material flows by plastic flow or is dislodged by brittle fracture.

4.) **Corrosive Wear**:--

Most metals are thermodynamically unstable in atmosphere & reat with oxygen to form oxides. These oxides form layer or scales over the surface. These scales are very loosely bonded to the surface. They can be easily removed by treating it with acids, gases, alkalis, etc. these kind of wear creates pits 7 gradually harm the metal surface.

5.) **Fatigue Wear**:--

Fatigue Wear or fracture arises when the components is subjected to cyclic compression & tension above a threshold stress. The surface wears down in this process. It starts with the formation of microcraks & it gradually spreads & with repeated loading it actually grows to the surface. Vibration is the common cause of fatigue.

1.10SYMPTOMS OF WEAR:--

Table 1.2: Symptoms & appearance of worn out surface corresponding to each type of wear

Types of Wear	Symptoms	Appearance of worn out surface
Abrasive	Presence of clean furrows cut out by abrasive particles	Grooves
Adhesive	Metal Transform is the main symptom	Seizure, catering rough & torn out surfaces.
Erosion	Presence of abrasive in a fast moving fluid medium & short abrasion furrows.	Waves & troughs
Corrosion	Presence of metal corrosion products.	Rough pits or depression.
Fatigue	Presence of surface or subsurface cracks accompanied by pits & spalls	Sharp & angular edges around pits.

Hence taking the importance of composites & specifically polymer reinforced composite we prepare a rice husk ceramic composite using rice husk ash & epoxy resin. The composites are to be prepared with different volume fraction of the filler i.e rice husk ash. The rate of wear is to be measured at varying load on a Pin-on-Disc apparatus.

Keeping all this in view the entire work has been divided into five chapters.

In the second chapter overview of the fabrication methods and work related to present investigations available in literatures are presented.

The third chapter represents the experimental methods employed to get the results.

In the fourth chapter we enumerated the results & discussed the conclusions & results we received during our experimental procedure.

2. 1   LITERATURE SURVEY

The literature survey was carried out as a part of the thesis work to get an overview of the production processes & properties of a polymer matrix composite. As the data on the service lives of composite structures is becoming gradually known, it can be said that they are more durable, maintain dimensional integrity, resist fatigue loading and are easily maintainable and repairable.

In recent years, natural fibers have drawn worldwide attention on a potential reinforcement material for the composite material. Usually the fiber reinforcement is done to obtain high strength and modulus. Hence it is necessary for the fibers to possess higher modulus. Then the matrix material, so that load is transferred to the fiber from the matrix effectively. Natural fiber to the maximum extent fulfills these criteria. And Rice Husk is one of such natural fiber. The RH Ash is the filler material that is got by carburizing the rice husk at 900degree Celsius.

Prasad BK et.al [7] while trying to find out the factors that control the abrasive wear of the zinc based alloy Silicon Carbide particles composites have reported that when silicon carbide from RHA is high enough to match the requirements. They also report that the Silicon Carbide can be either directly used as abrasive material or hot pressed with as abrasive material or hot pressed with composites.

The application of RHA [8-10] as a filler in plastics is relatively limited mainly to polypropylene (PP). As reported with an increase in the RHA loading, a PP composite flexural modulus & density increases, where as its tensile strength; breaking elongation & impact strength decreases; yet RHA still can replace some commercial fillers.

Navin Chand et. al [11] reports that the study on polyester filled with RHA. Their report says that both the tensile & impart strength of the resulting composites, decreases with increasing filler loading.

It is also reported that [12, 13] in addition to being used in rubber or plastics, RHA can also be used as a filler rubber/plastic blends.

Rozman H.D. et. al [14] studied the effects of chemical modifications of rice husk & reports that with chemical modification the reinforcing effects can be increased to an acceptable limit.

Abrasive wear performance in natural fiber reinforced polymer composites is very important aspect to exploit their usage in many applications. Chand et. al 1994 [15] have reported a new theory for abrasive wear mechanism for FRP composites.

After reviewing the literature available on rice husk it is clear that the interfacial bond between the reinforcing fiber and the resin matrix is important to realize the mechanical properties of the composite. Also, to obtain desired properties from a composite material, reinforcement and filler are added for polymer materials. Any additional improvement in mechanical and tribological properties is attained by filling particulate matters. The resistance of epoxy and polyester resin to crack propagation are relatively low. Fracture properties of epoxy resin can be improved by addition of other materials. Filler affects the mechanical properties according to their packing characteristics, size and interfacial bonding. It is also shown by some researchers that the fracture toughness of epoxy resin could be improved by addition of fly ash particles as fillers in glass-epoxy composite.

Hence the priority of this work is to develop a polymer matrix composite with rice husk ash as filler/fiber in epoxy matrix. The composite prepared will then be subjected to wear test.

2.2   MATERIAL SELECTION

2.2.1 Matrix Material

The matrix alloy should be chosen only after giving careful consideration to its chemical compatibility with the reinforcement and its own characteristics properties.

2.2.2   Why Polymer Matrix Selection?

Polymers are structurally more complex than metals or ceramic. They are cheap and easily processed. But polymers have lower strength and modulus and lower temperature use limits. Prolonged exposure to UV light and some solvents cause the degradation of polymer properties. Because of predominantly covalent bonding, polymers are poor conductors of heat and electricity. Polymers, however, are resistant to chemicals than metals. Polymers are giant chainlike molecules (hence the name macromolecules) with covalently bonded carbon atoms forms the backbone of the chain. The process of macromolecules formation from small ones is called polymerization; i.e, it is the process of joining many monomers, together to form polymer. Polymers used to manufacture advanced PMCs are of two types thermoset and thermoplastics resins.

a) **Thermoset resins**

Thermoset resins dominate the advanced composites industry, while thermoplastics have only a minor role. It requires addition of a hardener and impregnation onto a reinforcing material, followed by a curing step to produce a finished part. Some of the common thermoset resins are described briefly here.

Epoxy resins are relatively low molecular weight monomers with low shrinkage during cure. They can be partially cured and stored in that state. These cured epoxy resins have high chemical and corrosion resistance, good mechanical and thermal properties. But, they are more expensive compared to polyester resins. The second of the essential ingredients of an advanced composite system is the hardener. These compounds are very important because they control the rate of the reaction and determine the performance characteristics of the finished product. Since these compounds are catalysts for the reaction, they must contain active sites on their molecules. Some of the commonly used hardener in the advanced composites is the aromatic amines like 4.4 methylene-dianiline (MDA) and 4.4-sulfonylianiline (DDS)

b) Thermoplastic resins

Thermoplastics resins require only heat and pressure to form a finished product. Unlike thermoset resins, the thermoplastics resins can be reheated and reformed into another shape, if desired. Common examples include polyethylene, polystyrene, nylon, polycarbonate, polysulfone, polyphenylene sulfine etc. Polyamides, Polyimide, PEEK are relatively new

composite industry and are used in high temperature applications. These resins have better thermal stability and flame resistance than the epoxy resins. Polyamide based composites have excellent strength retention in hot and wet environment but they are brittle and have a very low elongation at break.

2.2.3   Reinforcement

Reinforcement increases the strength, stiffness and the temperature resistance and lowers the density of PMC. In order to achieve these properties the selection depends upon the type of reinforcement, its method of production and chemical compatibility with the matrix and the following aspects should be considered while selecting the reinforcement material.

- Size – diameter and aspect ratio(L/D)
- Shape – Chopped fiber, whisker, spherical or irregular particulates, flakes, etc:
- Surface morphology – smooth or corrugated and rough:
- Poly or single crystal
- Structural defects – voids, occluded material,
- Surface chemistry
- Material Impurities
- Inherent properties – strength, modulus and density.

2.2.4 Reinforcement Materials

Fibers as reinforcing material offer two advantages. Firstly, the bulk material is always stronger when produced as small diameter fibers due to the exclusion of large scale defects. Secondly, the fiber configuration allows tailoring of properties in specific directions. Fibers are added to the resin system to give strength to the finished part. The selection of reinforcing material is based upon the properties desired in the finished product. Fibers used in advanced composite manufacture come from various forms, such as yarns, roving, chopped strands, woven fabric and mats.

2.3   FABRICATION METHODS OF PMCs

There are two general divisions of composites manufacturing processes: **open molding** and **closed molding.** With open molding, the gel coat and laminate are exposed to the atmosphere during the fabrication process. In closed molding, the composite is processed in a two-part mold set, or within a vacuum bag. There are a variety of processing methods within the open and closed molding categories:

a) Open Molding Method: Hand Lay-Up, Spray-Up, Filament Winding

b) Closed Molding Method: Compression molding, Pultrusion, Vacuum Bag Molding, Vacuum Infusion Processing, Resin Transfer Molding (RTM)

2.3.1 Open Molding

Open molding process saturates fiber reinforcement with resin, using manual rollout techniques to consolidate the laminate and removing the entrapped air. A major factor of the operation is the transfer of resin from a drum or storage tanks to the mold. The means used to transport the resin, in many cases, characterizes the specific process method.

a) Hand Lay –Up

Hand lay-up is suitable for making a wide variety of composites products including: boats, tanks bath ware, truck/auto components, architectural products and many other products ranging from very small to very large. Production volume is low; however, it is feasible to produce substantial production quantities using multiple molds. Simple, single-cavity molds of fiberglass composites construction are generally used. Molds can range from very small to very large and are low cost in the spectrum of soft composites molds.

Gel coat is applied to the mold using a spray gun for a high-quality surface. When the gel coat has cured, roll stock fiberglass reinforcement is manually placed on the mold. The lamination resin is applied by pouring, brushing, or using a paint roller. FRP rollers, paint rollers,

or squeegees are used to consolidate the laminate, wetting the reinforcement, and removing entrapped air. Subsequent layers of fiberglass reinforcement are added to build laminate thickness (Fig 2.1).

Simplest method offering low-cost tooling, simple processing and wide range of part sizes are the major advantages of this process. Design changes are readily made. There is a minimum investment in equipment. With skilled operators, good production rates consistent quality is obtainable.
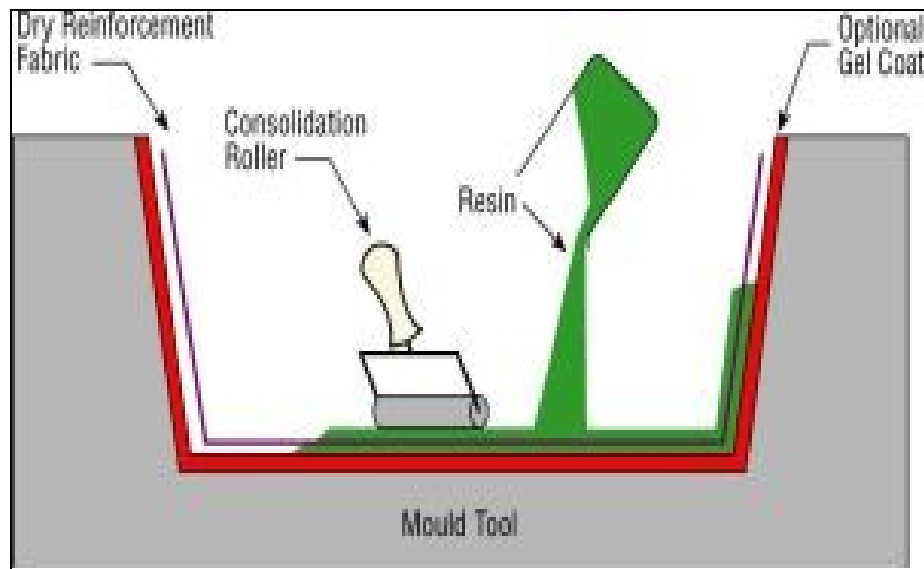

Fig 2.1 Hand Lay-Up Technique

3. MATERIALS AND METHODS

3.1 RAW MATERIALS

Raw materials used in this experimental work are listed below:

1. Rice Husk
2. Epoxy resin
3. Hardener

3.1.1 Rice Husk

Rice husk is an agricultural waste material abundantly available in all most all over the world. They are the natural sheaths that formed on rice grains during their growth. Removal during the refining of paddy, these husks have no commercial interest. But in some places they may be used as fuels although they have very low calorific value. The annual rice husk production in India amounts is generally approximately 3 million tons [16]. World wide production of rice husk is about 120 million tons per year. That makes the rice husk one of the largest readily available but also one of the most under-utilized resources. Increase in the environmental awareness has led to a growing interest in researching ways of an effective utilization of rice by-product, from which rice husk is particularly valuable due to its high content of amorphous silica. The rice husk contains 80 percent organic volatile materials and remaining 20 percent silica. The rice husk ash (RHA) contains 85%-95% amorphous silica [17]. Silica obtained is quiet reactive & depends upon factors like the degree of firing and is used for making insulating materials, refractory bricks [18, 19], Portland cement, masonry cement and pottery ware. It is used as filler materials in paints and in fertilizers [20] etc. rice husk ash has also been used in aluminum alloy for increasing abrasion resistance. The chemical composition of the rice husk ash varies from sample to sample which may be due to the different geographical conditions, type of paddy, climatic conditions and type of fertilizer used.

It was found that RH Ceramics contains amorphous silica in addition to amorphous carbon as the main constituents. Compared to the conventional sources of silica rice husk ash as a ceramic raw material possess advantages like fine particles size and higher reactivity due to its amorphous nature. Many authors have concluded that rice husk is an excellent source of high

grade amorphous silica. Accordingly silica is used in different industries and products like rubber industry as a reinforcing agent, in tooth pastes as a cleaning agent, as an anti-caking agent in salts, in cosmetics etc.

But it is interesting to note that rice husk contains 20% ash, 22% lignin, 38% cellulose, 18% pentosans and 2% moisture. A typical composition of ash is [18] 95% SiO_2, 2% K_2O, 1% CaO, P_2O_5 & Na_2O_3, Fe_2O_3 & MgO. The silica in rice husk originally is present in amorphous form but after carburizing it becomes crystalline.

In this work the new hard porous carbon material called the RH (rice husk) Ceramic has been developed and the tribological properties of the RH Ceramic Epoxy Composite has been studied using a pin-on-disc machine.

3.1.2 Epoxy resin

ARALDITE(LY 556) Standard Epoxy Adhesive was used as the resin having the following outstanding properties has been used as the matrix material.

   a. Excellent adhesion to different materials.
   b. High resistance to chemical and atmospheric attack.
   c. High dimensional stability.
   d. Free from internal stresses.
   e. Excellent mechanical and electrical properties.
   f. Odorless, tasteless and completely nontoxic.
   g. Negligible shrinkage.

3.1.3   Hardener

In the present work hardener (HY951) is used. This has a viscosity of 10-20 MPa at 25ºc.

3.2 PREPARATION OF COMPOSITES:

The following procedure has been adopted for the preparation of the specimen.

(a) Rice Husk Ceramic filler Preparation

Finely milled rice husk was collected from a local rice mill. The milled rice husk contains many impurities like dust, small rice particles, and fine sand particles. These impurities need to

be cleaned so as we get pure rice husk. For this purpose we wash the rice husk thoroughly with water. Care is taken so as the rice husk is not washed out in this process. This kind of wash removes major impurities like sand particles or dust particles & small rice particles remained. After it is washed thoroughly we dry them up in a desiccators or in the sun. The husk is thoroughly dried so as no amount of moisture remains in this process. Then to again separate out larger husk particles & remained amount of rice particles we sieve the rice husk thoroughly. Finally the husk is ready to be carburized. For our experimental process we used Nitrogen atmosphere (N_2) & we carry out the carburizing process in the nitrogen atmosphere. For this we used a furnace & to ensure uninterrupted supply of nitrogen we used a nitrogen generator. Now the dried rice husk is placed in small porcelain crucibles & put into the furnace chamber. The nitrogen generator is attached. The furnace is an automated one so we fix the step with which the temperature will increase. We start with a furnace temperature of 300°C & gradually go up to 900°C in a step function of 5°C each minute. Hence the furnace takes 120 min to heat up to the required temperature .At the same temperature of 900°C it is maintained for 4 hours. This ensures that rice husk is properly turned into ash. Then the furnace is turned off & allowed to cool .It takes around 3 hours to cool. After it is sufficiently cooled the furnace chamber is opened & then the rice husk is taken out & kept in a sealed envelope so that it doesn't come in contact of atmosphere. Some important points to remember while carburizing the husk is, Nitrogen atmosphere while carburizing should take place in 99% Nitrogen atmosphere otherwise the ash may undergo oxidation & perfect vacuum should be maintained before the start of the process. The amount of ash to be collected or required for the experiment is calculated by the % of volume fraction technique whose tabulation & calculation is shown in the subsequent pages.

(b) Composite preparation

After the filler material is prepared the resin for preparation of the composite is carefully choosen. Now we prepare composites with varying degrees of filler & resin percentage (i.e. 10% filler & 90% resins, 15% filler & 85% resins, 20% filler & 80% resins, 25% filler & 75% resins, 30% filler & 70% resins). The required weights of filler & polymer or resin for this purpose are calculated as shown in the calculation part.

Now the resin & filler is mixed & it is then put into a box jig to form cylindrical components of 3.5 cm long & 10 mm diameter. Load is applied upon it & it is left for 48-72 hours to form solid

cylindrical components. After 48-72 hours the components are taken out & placed in a sealed envelope.

Then the percentage of voids is calculated using the void fraction calculation formula which is shown in the calculation part.

After preparation of the composite & the cylindrucal components the components are put to wear test. This test is performed on a pin on disc apparatus. The apparatus specifications & the experimental methodology are discussed below.

3.3 WEAR TEST:--

Fig 3.1: Set up to perform an Abrasive wear test on a pin on the disc

a.) Pin on Disc type Tribometer Friction & Wear Machine

The Tribometer uses a pin-on-disk system to measure wear. The unit consists of a gimbaled arm to which the pin is attached, a fixture which accommodates disks up to 165 mm in diameter & 8 mm thick, an electronic force sensor for measuring the friction force, and a computer software (on Lab view platform) for displaying the parameters, printing, or storing data for analysis. The motor driven turntable produces up to 3000 rpm. Wear is quantified by measuring the wear groove with a profilometer (to be ordered separately) and measuring the amount of material removed. Users simply specify the turntable speed, the load, and any other desired test variables such as friction limit and number of rotations.
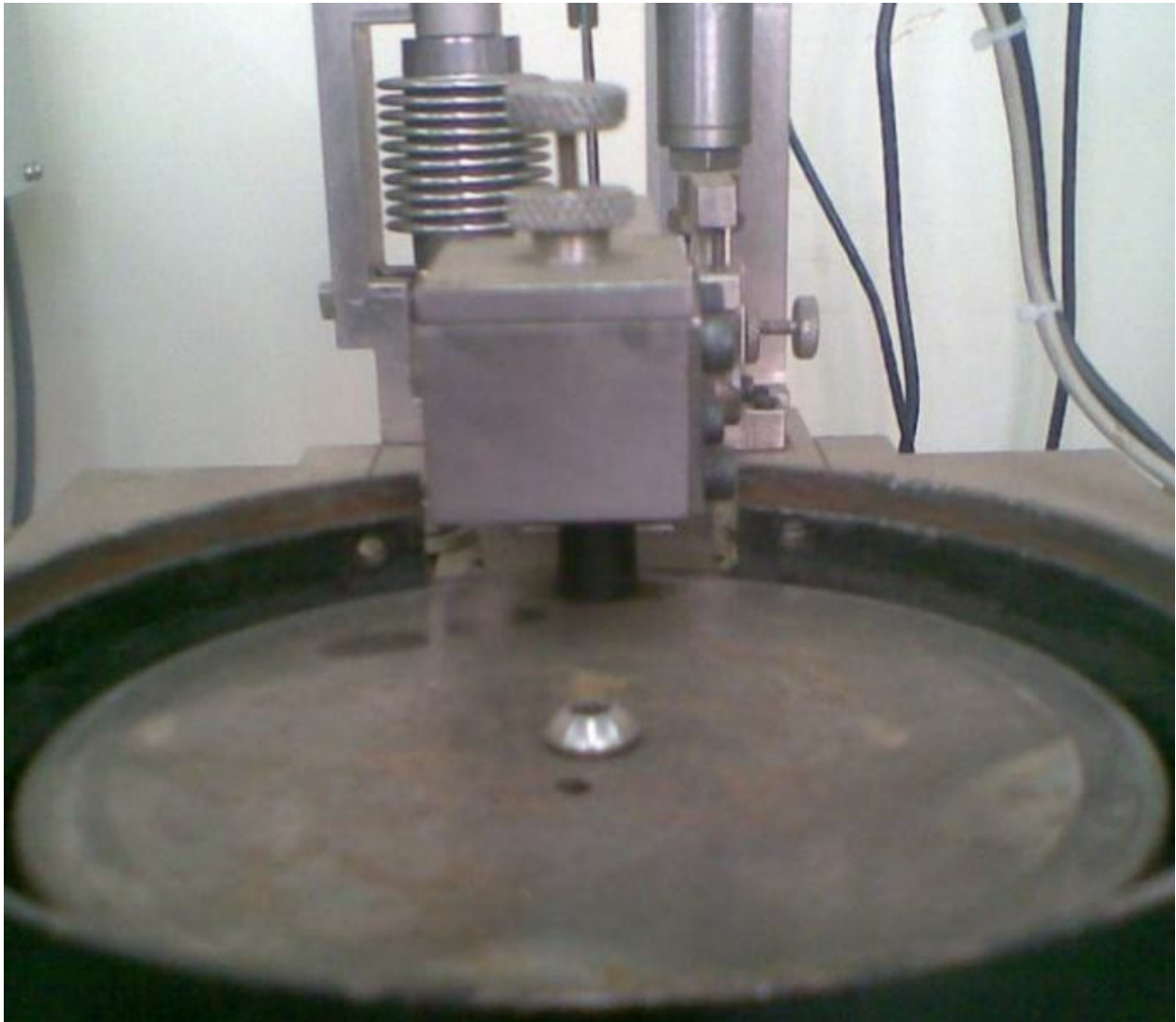

Fig 3.2 Specimen (composite) loaded as pin for performing wear test

Designed for unattended use, a user need only place the test material into turntable fixture and specify the test variables. A pre-determined Hertzian pressure is automatically applied to the pin using a system of weights. Rotating the turntable while applying this force to the pin includes sliding wear as well as a friction force. Since pins can be fabricated from a wide range of materials virtually any combination of metal, glass, plastic, composite, or ceramic substrates can be tested.

Software included with this model provides for quick calculation of the Hertzian pressure between the pin and disk. The cup-like (housing) enclosed fixture permits the use of liquid lubricants during a wear test (optionally).

b.) Features & specifications

Table 3.1: Specification of the pin-on-disc apparatus

Rotational Speed	Up to 200 rpm
Diameter of Track	40 mm to 118 mm
Load Range	Up to 200 N
Loading Lever Ratio	1:1 ratio
Disc Type	Diameter = 120 mm ; Thickness = 8mm
Pin Size	6 mm-12 mm
Software	MAGVIEW – 2007
Wear or Displacement	-2000 microns to + 2000 microns
Frictional Force	Up to 200 N
Drive	1.1 KW D.C. motor, constant torque
Motor Control	Thyrister converter, with motor protection
Power	230 Volt Line, 15 amps, single phase, 50 Hz. A.C.

c.) Data Acquisition

The friction coefficient signal is displayed in real time on a PC Screen. Data can be viewed as it is logged for the entire specified test duration, which can be recalled later for detailed analysis. The software allows 9 different logged test files for on-line analysis / mapping the software displays the test time, turn count, linear velocity, and user-defined test parameters. This data can be stored and printed along with the friction traces.

Purpose

Records friction and wear in sliding contact in dry, lubricated, controlled environment and partial vacuum.

d.) Application

Fundamental wear studies. Wear map ping and PV diagrams. Friction and wear testing of metals, ceramics, soft and hard coatings, plastics, polymers and composites, lubricants, cutting fluids, heat processed samples.

Features

- Displays and records friction, wear and pin temperature (optional).
- Dry, lubricated, controlled environment and vacuum tests (optional).
- Wide sliding speed range (continuously variable thru the variable drive)
- User can program RAMP tests to be specified by the user (available optionally)

Standards

ASTM G-99

Instrumentation and Data Acquisition System for the measurement of

- RPM
- Wear
- Frictional force
- Temperature
- Electrical Contact resistance measurement (40 mV Signal)

PC acquires data online and displays it in several ways. Graphs of individual tests can be printed. Results of different tests can be superimposed for comparative viewing. Data can be exported to other software.

- Tests at ambient temperature
- Dead weight loading
- Electrical contact resistance measurement
- Displays Load, Friction, temp, rpm / speed on the display panel
- Auto on/off (timer)

3.4 STANDARD METHODOLOGY TO CONDUCT THE WEAR TEST

The amount of wear in any system will, in general, depend upon the number of system factors such as the applied load, machine characteristics, sliding speed, sliding distance, the environment, and the material properties. The value of any wear test method lies in predicting the relative ranking of material combinations. Since the pin-on-disk test method does not attempt to duplicate all the conditions that may be experienced in service (for example; lubrication, load, pressure, contact geometry, removal of wear debris, and presence of corrosive environment), there is no insurance that the test will predict the wear rate of a given material under conditions differing from those in the test.
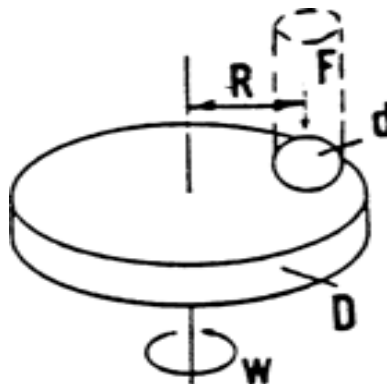
FIG. 3.3 Schematic of pin-on-disk wears test system.

Note—F is the normal force on the pin, d is the pin or ball diameter, D is the disk diameter, R is the wear track radius, and w is the rotation velocity of the disk.

a.) Scope of the experimental setup

1.) This test method covers a laboratory procedure for determining the wear of materials during sliding using a pin-on-disk apparatus. Materials are tested in pairs under nominally non-abrasive conditions. The principal areas of experimental attention in using this type of apparatus to measure wear are described. The coefficient of friction may also be determined.

2.) The values stated in SI units are to be regarded as standard.

3.5 EXPERIMENTAL PROCEDURE

1.) First of all the pin or the sample is mounted on to the arm of the triobometer.

2.) Then the desired load is applied on to the pin by a pulley arrangement. The loads vary from 5N, 10N, 15N & 20N.

3.) First of all 5N load is added & the 10% sample component is loaded as the pin.

4.) A velocity is selected to be given to the disc. A motor is supplied with electric power which transmits the energy into rotary motion of the disc. Initially 30 rpm (0.157m/s) is chosen & the disc is made to rotate at that speed for 300 sec.

5.) The friction & temperature rise is recorded by the electronic data accusation system.

6.) The test is run for 4 times for each sample. The average value of coefficient of friction is computed from the data. And after each run the weight loss is measured using a weighing machine.

7.) The weight loss for each run is computed by getting the difference between the initial weight & the final weight. Then the average weight loss is got after 4 runs are completed.

8.) Then with the same load & 15%, 20%, 25% & 30% filler component we repeat the same procedure & get the weight loss.

9.) After that we change the load to 10N & again run the experiment with the components with varying filler %age keeping the velocity constant.

10.) Finally the weight loss is tabulated as shown below.

11.) From the weight loss we can get the wear rate & the specific wear rate by using the formula.

From the experiment we get 2 important data i.e. the weight loss or wear in a specific time & the coefficient of friction for the velocity of 30 rpm or 0.157m/s

4.1 CALCULATIONS:--

Table 4.1:-- Calculation of weight of filler & polymer required for making the composite

Sl.no	Volume of composite (Vc)	% of Filler	Volume of filler(Vf) (in cc)	Volume of Polymer (Vp) (in cc)	Density of filler (in gm/cc)	Density of Polymer (in gm/cc)	Weight of filler (in gm)	Weight of polymer (in gm)
1	2.75	10	.275	2.475	2.06	1.1	.5665	2.7225
2	2.75	15	.4125	2.3375	2.06	1.1	.84975	2.57125
3	2.75	20	.55	2.2	2.06	1.1	1.133	2.42
4	2.75	25	.6875	2.0625	2.06	1.1	1.41625	2.26875
5	2.75	30	.825	1.925	2.06	1.1	1.6995	2.1175

Table 4.2:-- Calculation of the total weight required being required

Total samples for Sl.no 1-5	Total weight of filler (8*weight of the filler)	Total weight of the polymer (8*weight of the polymer)
8	4.532	21.78
8	6.798	20.57
8	9.064	19.36
8	11.33	18.15
8	13.596	16.94
Total nos. of samples: 40	Total Weight:-- 45.32 gms	Total weight:-- 96.8 gms

For void calculation:--

Density of polymer=1.0974 gm/cc
Density of Fiber=2.25 gm/cc
Theoretical Density= T
Experimental density =M

$T = 100/[(R/D)+(r/d)]$ where:--

R = % of Resin
D = Density of Resin
r = % of Fiber
d = Density of Fiber

Table 4.3:-- Calculation of Theoretical Density (T)

% of Resin	% of Fiber	Density of Resin (in gm/cc)	Density of fiber (in gm/cc)	Theoretical Density= T (in gm/cc)
90	10	1.1	2.25	1.159
85	15	1.1	2.25	1.191
80	20	1.1	2.25	1.225
75	25	1.1	2.25	1.261
70	30	1.1	2.25	1.299

Table 4.4:-- Calculation of void percentage

Voids content V=100(T - M)/T

% of fiber	T (in gm/cc)	M (in gm/cc)	T-M(in gm/cc)	V (in %age)
10	1.159	1.143	0.016	1.402
15	1.191	1.171	0.020	1.737
20	1.225	1.201	0.024	2.019
25	1.261	1.229	0.032	2.616
30	1.299	1.262	0.037	2.949

Fig 4.1:-- Plot of percentage of filler vs measured density (M)
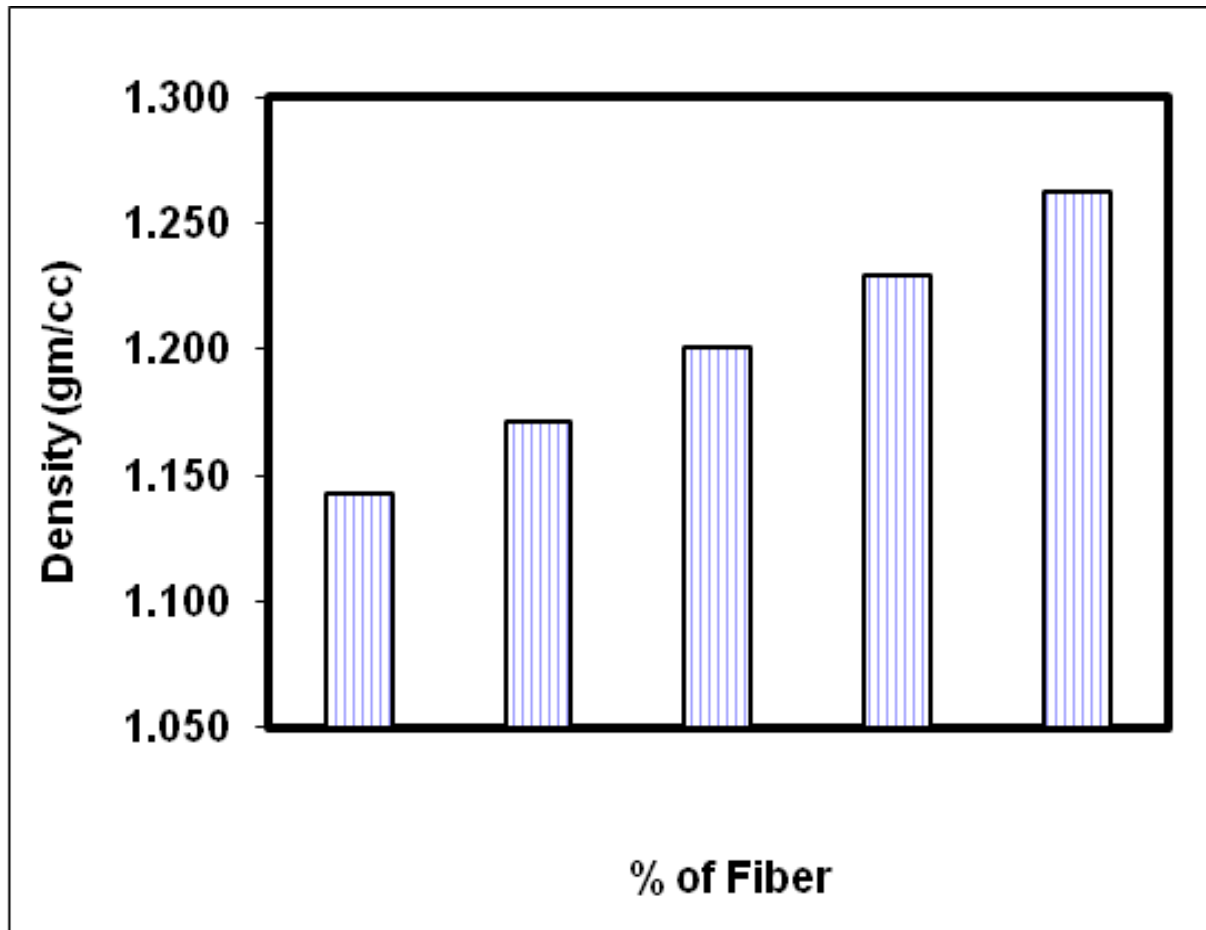
4.2 TEST RESULT

a.) The Coefficient of Friction

Table 4.5:-- The value of coefficient of friction vs. time when various sample underwent the wear test for 300 seconds at a velocity of 0.157 m/s.

| Sl.no	TIME(in sec)	10%	15%	20%	25%	30%
1	1.229	0.078	0.085	0.081	0.087	0.082
2	5.354	0.361	0.371	0.352	0.369	0.353
3	10.526	0.597	0.61	0.58	0.6	0.57
4	15.698	0.741	0.757	0.728	0.742	0.707
5	20.869	0.834	0.844	0.824	0.833	0.794
6	26.041	0.891	0.898	0.884	0.889	0.85
7	31.198	0.927	0.932	0.922	0.926	0.885
8	36.369	0.95	0.955	0.946	0.947	0.91
9	41.526	0.963	0.971	0.962	0.962	0.927
70	46.698	0.97	0.977	0.974	0.974	0.94
11	51.854	0.974	0.985	0.981	0.982	0.95
12	57.026	0.973	0.993	0.985	0.99	0.958
13	62.198	0.972	0.997	0.987	0.993	0.963
14	67.354	0.972	1	0.984	0.998	0.969
15	72.526	0.972	1.005	0.982	1.002	0.973
16	77.698	0.971	1.007	0.984	1.006	0.977
17	82.854	0.971	1.007	0.988	1.01	0.981
18	88.01	0.97	1.006	0.992	1.014	0.983
19	93.182	0.967	1.008	0.996	1.017	0.985
20	98.354	0.967	1.007	0.999	1.022	0.988
21	103.51	0.966	1.006	0.997	1.024	0.988
22	108.682	0.965	1.004	0.994	1.026	0.989
23	113.838	0.963	0.999	0.989	1.028	0.99
24	119.01	0.96	0.997	0.986	1.03	0.991
25	124.182	0.959	0.99	0.985	1.031	0.994
26	129.338	0.955	0.988	0.987	1.028	0.997
27	134.51	0.954	0.986	0.991	1.027	0.999
28	139.666	0.953	0.981	0.993	1.026	0.998
29	144.838	0.952	0.982	0.992	1.024	0.995
30	149.994	0.95	0.982	0.992	1.025	0.995
31	155.166	0.949	0.979	0.993	1.024	0.997
32	160.338	0.947	0.98	0.995	1.023	0.998
33	165.494	0.945	0.977	0.999	1.022	0.998
34	170.666	0.946	0.977	1.001	1.019	0.999
35	175.838	0.944	0.978	1.002	1.016	1
36	180.994	0.944	0.974	1	1.013	1.001
37	186.166	0.944	0.973	0.996	1.011	1.002
38	191.323	0.945	0.97	0.993	1.011	1
39	196.494	0.945	0.969	0.991	1.009	1.001
40	201.666	0.945	0.97	0.99	1.008	1.001
41	206.823	0.945	0.971	0.993	1.007	1.001

|					
42	212.01	0.944	0.975	0.996	1.006	0.998
43	217.166	0.945	0.975	0.998	1.004	0.998
44	222.338	0.945	0.973	0.998	1.004	1.001
45	227.494	0.944	0.974	1	1.003	1.001
46	232.666	0.943	0.971	1.005	1.003	1.001
47	237.823	0.946	0.97	1.007	1.002	1
48	242.994	0.946	0.966	1.007	1.002	0.999
49	248.151	0.947	0.964	1.007	0.999	0.997
50	253.323	0.949	0.966	1.007	0.996	0.996
51	258.479	0.948	0.963	1.002	0.992	0.996
52	263.651	0.949	0.963	0.998	0.991	0.996
53	268.807	0.95	0.961	0.993	0.99	0.996
54	273.979	0.95	0.957	0.991	0.991	0.994
55	279.135	0.95	0.955	0.991	0.991	0.994
56	284.307	0.95	0.949	0.991	0.992	0.994
57	289.463	0.952	0.948	0.997	0.993	0.993
58	294.666	0.951	0.947	1.003	0.994	0.993
59	299.823	0.952	0.947	1.004	0.993	0.993

Fig 4.2 Plot of COF (y-axis) vs. Time (x-axis)

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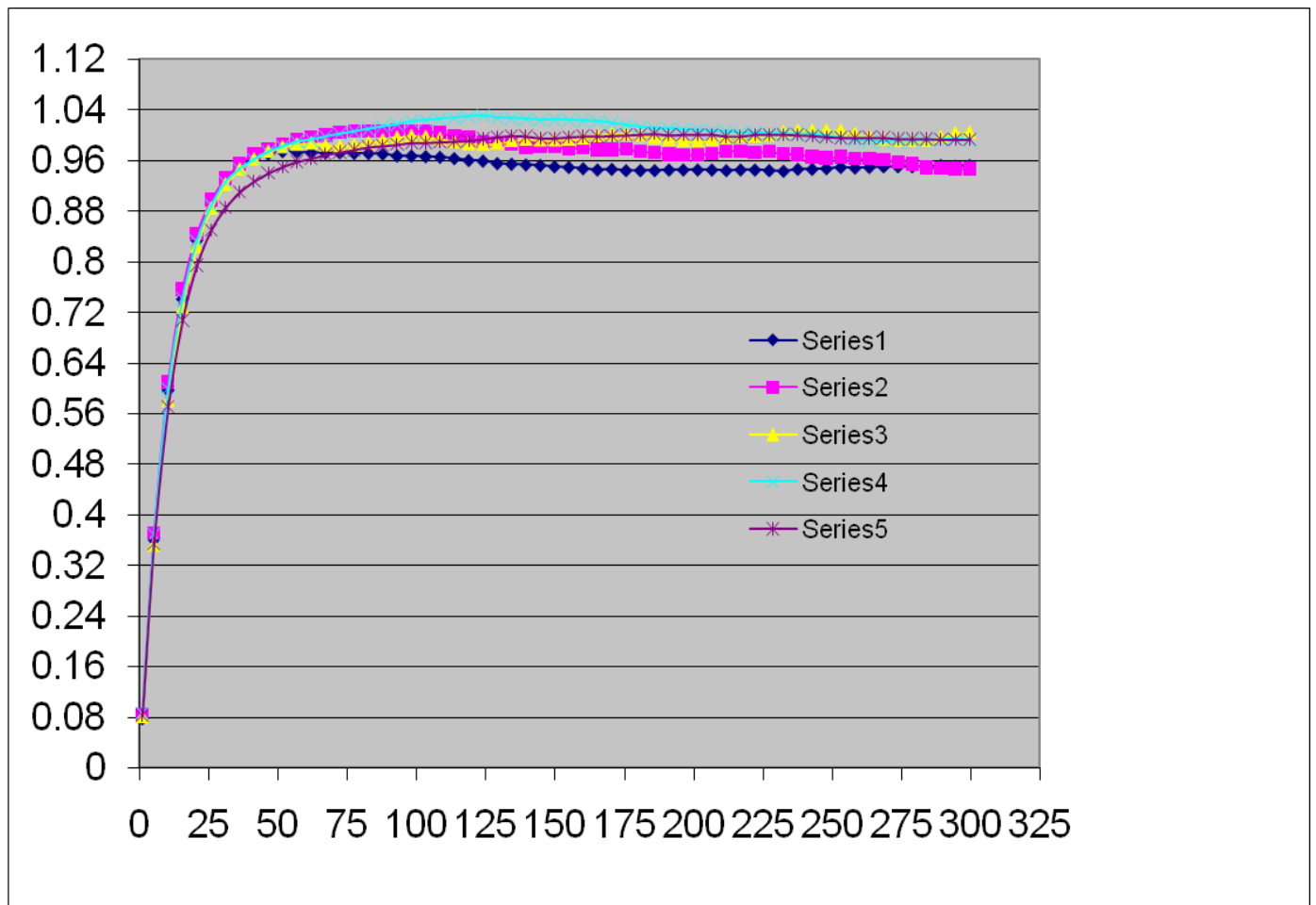
a.) The determination of weight loss:--

Table 4.6:-- Weight Loss (in gm) during wear test in 300 seconds:

V=0.157 m/s					
Load (in N)	10% filler	15% filler	20% filler	25% filler	30% filler
5	.08	.07	.06	.05	.04
10	.13	.12	.1	.08	.06
15	.2	.16	.14	.12	.09
20	.26	.22	.18	.17	.14

Fig 4.3:-- Plot of weight loss vs. Load for each sample
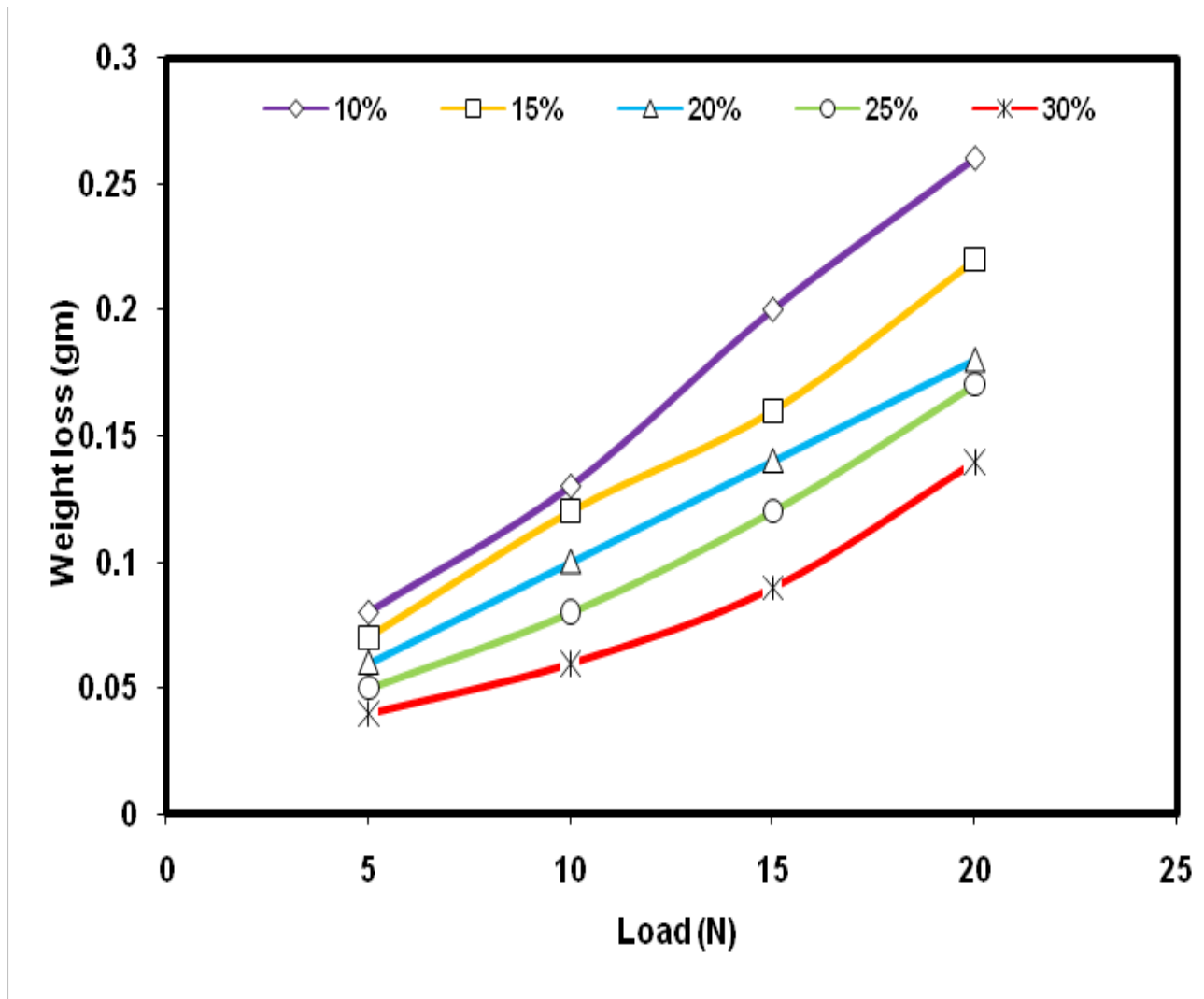
a.) To find dimension less wear rate:--

Dimensionless wear rate = W= (M1-M2)/ (ρ.A.v.t)

For all samples:-
 Area (A) = 3.14
 Density (ρ) = Experimental density: we get the values from table 2
V = 31.4 cm/s &
Time = 1200 seconds
L = V*Time = 37680cc/sec in each case

Table 4.7: -- Dimensionless wear rate under varying loads for various composites.

Sl.No	Load(N)	W for 10%	W for 15%	W for 20%	W for 25%	W for 30%
1.	5	1.26E-06	1.01E-06	9.14E-07	6.87E-07	5.35E-07
2.	10	2.22E-06	1.66E-06	1.48E-06	1.24E-06	8.03E-07
3.	15	2.88E-06	2.52E-06	2.11E-06	1.65E-06	1.2E-06
4.	20	4.51E-06	3.46E-06	2.88E-06	2.47E-06	1.61E-06

Fig 4.4:-- Plot of Dimensionless Wear rate vs. Load for each sample
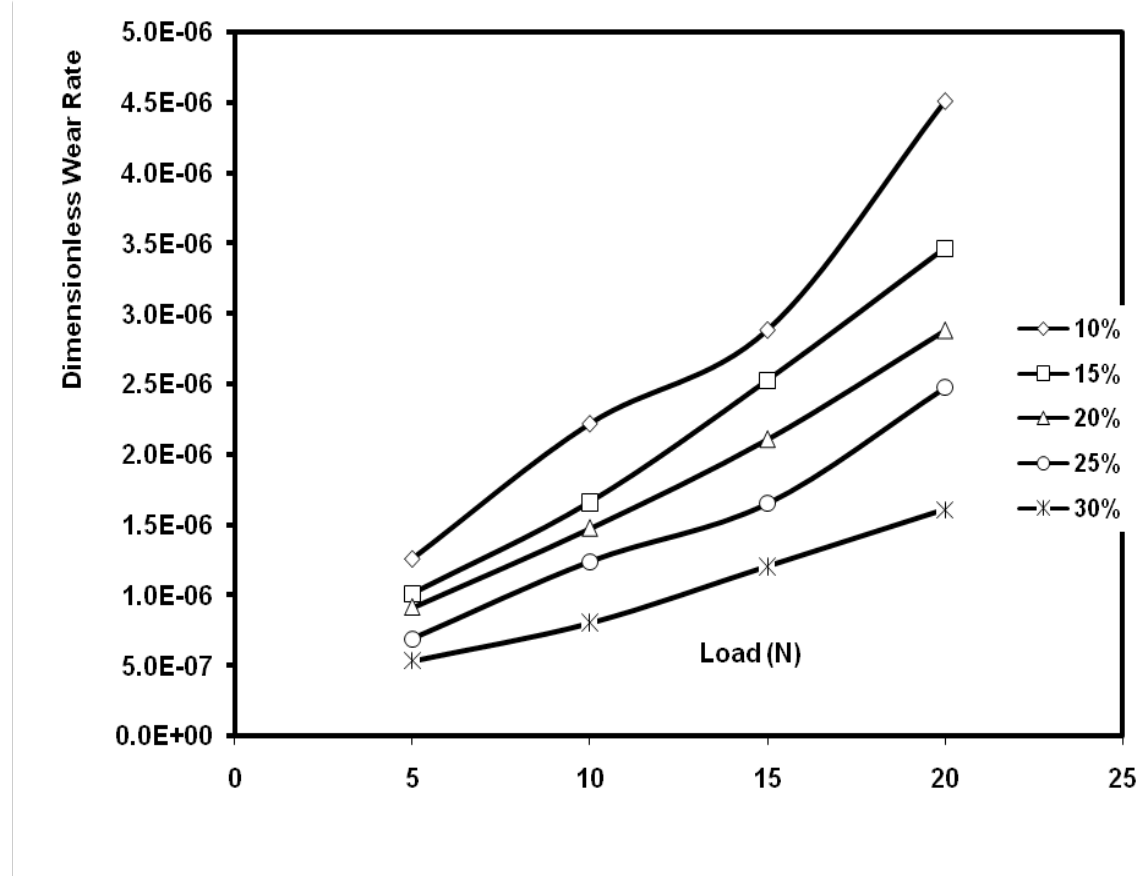
a.) Detemaination of Specific wear rate :--

Specific wear rate =k0 = w/ (ρ x D x L)

Where w = the weight loss from table 5 at velocity of 0.157 m/s

ρ = the measured density of the sample which we get from table 2 = M
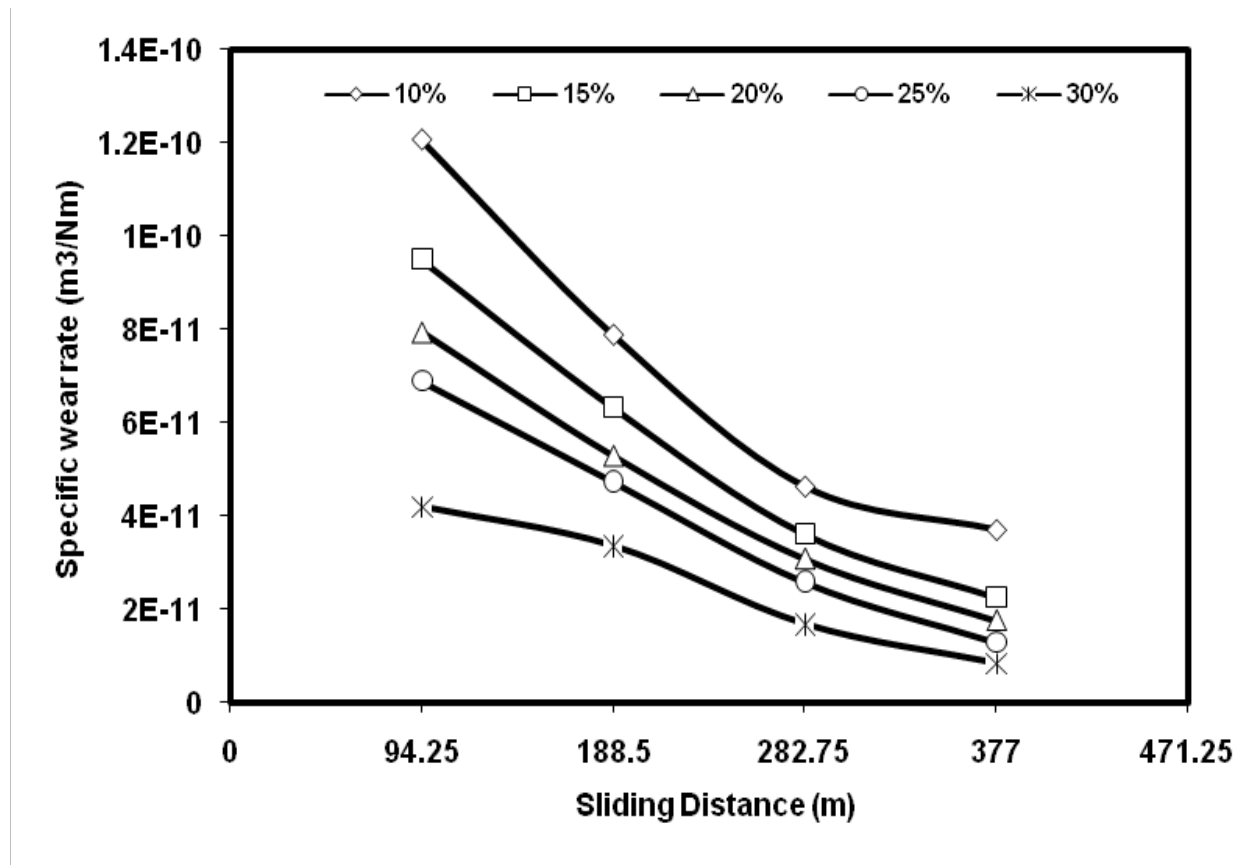
D = Diameter of the Sample = 10 mm

L = Traveling distance

For 20N load the specific wear is shown in the table:--

Table 4.8: -- Specific wear rate (K_0) of the sample under load of 20N & velocity of 0.157 m/s

Sl.no	Distance in m	10% filler	15% filler	20% filler	25% filler	30% filler
1.	94.25	1.21E-10	9.51E-11	7.95E-11	6.91E-11	4.2E-11
2.	188.5	7.89E-11	6.34E-11	5.3E-11	4.75E-11	3.36E-11
3.	282.75	4.64E-11	3.62E-11	3.09E-11	2.59E-11	1.68E-11
4.	377	3.71E-11	2.27E-11	1.77E-11	1.29E-11	8.41E-12

Fig 4.5:-- Plot of specific wear rate vs. sliding distance (in m)

For 5N load the specific wear is shown in the table:--

Table 4.9: -- Specific wear rate (K_0) of the sample under load of 20N & velocity of 0.157 m/s

Sl.no	Distance in m	10% filler	15% filler	20% filler	25% filler	30% filler
1.	94.25	6.03E-11	4.98E-11	3.98E-11	3.45E-11	2.94E-11
2.	188.5	3.71E-11	3.17E-11	2.65E-11	2.16E-11	1.68E-11
3.	282.75	1.86E-11	1.36E-11	8.83E-12	1.29E-11	8.41E-12
4.	377	4.64E-12	4.53E-12	4.42E-12	4.32E-12	4.20E-12

Fig 4.6:-- Plot of specific wear rate vs. sliding distance (in m)

CHAPTER – 5
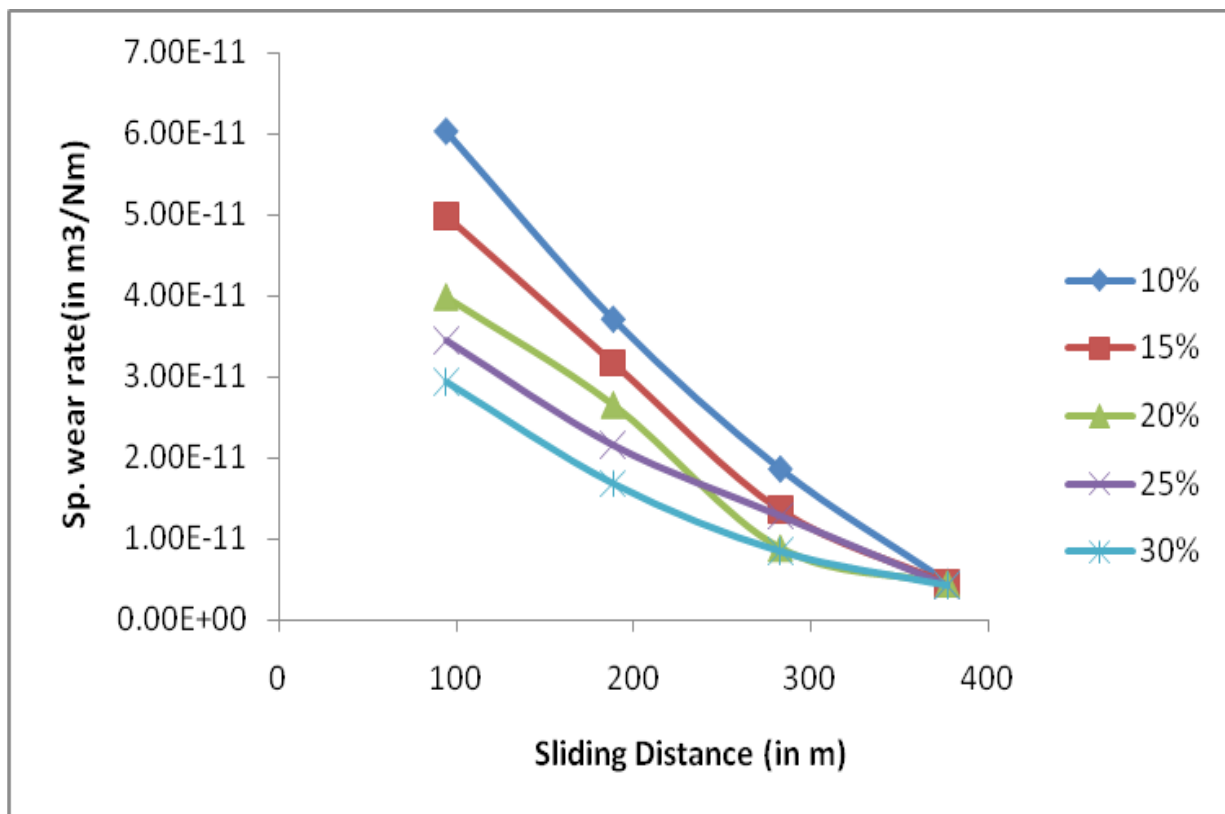
5.1   CONCLUSIONS

The following conclusions are drawn from the above studies.

1.) There is an increase in the percentage of voids in the composite when the percentage of filler i.e. the rice husk ash in the composite increases.(table 4.4)

2.) The coefficient of friction almost remains constant for a particular matrix constituent, for the whole of the test period as it is clear from the table 4.5.

3.) With increase in the percentage of fiber i.e. the rice husk ash in the composite the wear rate decreases even though the other environment variables remaining same. (Table 4.6)

4.) For a given composite with a defined constituent of fiber & matrix the wear rate increases due to increase in the Load. (Table 4.6)

5.) The dimensionless wear rate decreases with the increase of filler or rice husk ash in the composite & with increase in load for a particular composite increase with increase in load. (table 4.7)

6.) The specific wear rate decreases with the increase of filler or rice husk ash in the composite & with increase in load for a particular composite increase with increase in load. (table 4.8)

RECOMMENDATION FOR FURTHER RESEARCH

From this work, it is observed that the wear rate decreases with increase of filler percentage i.e. rice husk in the composite & also the wear rate increases in the load. We did the experiment for a single velocity. This can be extended to other types of lay out.

1. The observation of wear rate can be noted with increase & decrease of velocity of the disc in pin-on-disc.

2. The rice husk was carburized at 900°C. But the wear behavior of the rice husk can be studied by increasing the temperature at which the carburizing takes pale e.g. 1200°C & 1400°C.

3. Mechanical Tests like tensile & compressive, three point bend test etc. can also be performed upon the composite material of variable constituents we synthesized & can be studied to get its mechanical properties.

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