Experimental investigation of Tribological Properties of Compressor Piston Ring with PEEK

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Abstract - **In the oil less reciprocating compressor, it is not necessary for lubricating oil to be fed into a piston ring, a piston or a cylinder. Lubricating oil is not introduced into a compression chamber in the cylinder, and is not contained in compressed air discharged from the compressor. Thus, oil less reciprocating air compressors are widely used in medical, food, chemical, textile or oxygen feeding field that do not like oil compressed air, or among users who are troubled in feed and maintenance of lubricating oil. Now a day's pure PTFE (polytetrafluoroethylene) is widely used as a piston ring material which is self-lubricating and subjects to lower coefficient of friction, but problem with PTFE is that, it subjects to high wear rate, which can be reduced by adding suitable fillers. In this study, polyetheretherketone (PEEK) is taken as a base polymer material, and PTFE used as a solid lubricant. These polymer materials reinforced with glass fibers (GF) and additives like MoS2, Bronze. The effects of time, load, sliding velocity and filler content in PEEK/PTFE are experimentally examined. A comparative analysis of five composites (1) PEEK, (2) 70%PEEK/15%PTFE/15%glassfibers, (3) 65%PEEK/15%PTFE/15%GF/5%MoS2, (4) 50%PEEK/15%PTFE/15%GF/5%MoS2/15%BRONZ, (5) 45%PEEK/15%PTFE/15%GF/5%MoS2/20%BRONZ is presented showing how properties of PEEK can be improved by addition of filler content. The results of experiments are proving that the wear is strongly influenced by the composition of filler content. It was found that, in PEEK/PTFE addition of glass fibers with MoS2 shows the higher wear resistance. Also while increasing the percentage of BRONZ in polymer composite resist the wear rate.**

keywords - **Reciprocating compressor, lubrication, piston ring, composite material, wear rate,**

I. Introduction

In the oil less reciprocating compressor, it is not necessary for lubricating oil to be fed into a piston ring, a piston or a cylinder. Lubricating oil is not introduced into a compression chamber in the cylinder, and is not contained in compressed air discharged from the compressor. Thus, oil less reciprocating air compressors are widely used in medical, food, chemical, textile or oxygen feeding field that do not like oil compressed air, or among users who are troubled in feed and maintenance of lubricating oil. Generally, oil less reciprocating air compressors usable under pressure range below 1mpa. The piston ring-cylinder assembly has a play very important role in the air compressor. The materials used for piston ring and the cylinder jacket are cast iron, alloy and stainless steel. The sliding contact between the assemblies, this is tighter when the radial contact pressure between the two parts is higher. This, however, increase the friction between the two parts resulting in a number of undesired effect such as wear, higher temperature and pressure in the area, higher mechanical energy consumption to overcome the friction. Due to high pressure and temperature the piston ring worn to decrease sealing capability of the piston ring. Also poor to decrease discharge performance of the oil less reciprocating air compressor. Furthermore, leakage is likely to generate abnormal sound. To solve such disadvantages, the selection of ring material is important task.

Therefore, in this research the focus is on the selection of material for such an oil less reciprocating air compressor piston rings.

This has led to development of new non-metallic compounds, which through a program of testing has introduced of such special polymer composite for air compressors piston rings to increase the life several times. As many of the polymers are inferior in load carrying capacity when compared to other engineering materials such as metals, it is useful to add fillers to increase the strength and thus reduce wear. These fillers are glass fibre, carbon fibre, aramid fibre and particulate fillers in polymer matrices such as epoxy, phenolic. Fillers are also added to polymers to modify their friction property and thus wear performance.

II. Objective of Research

To develop an oil-free piston ring polymer composite material for a reciprocating compressor, by conducting the wear test and to study the effect of time on

a. wear
b. coefficient of friction
c. Frictional Force.

To find percentage improvement in wear resistance due to addition of various fillers.

III. Scope of Research

The present work is to develop and characterize a new class of composites with a polymer called poly-ether-ether-ketone (PEEK) as the matrix and glass fiber as the reinforcing material. Their tribological characterization is done.

Attempt is made to use self-lubricants like PTFE, as filler in these fiber reinforced polymer matrix composites. These increases wear resistance.

MoS2 and Bronze powders are also filled in the glass fiber reinforced poly-ether ether-ketone matrix and tribological characterization of the resulting new composite is done.

This work is expected to introduce a new class of functional polymer composites suitable for tribological applications.

IV. Methodology

The experiment was performed in following steps:

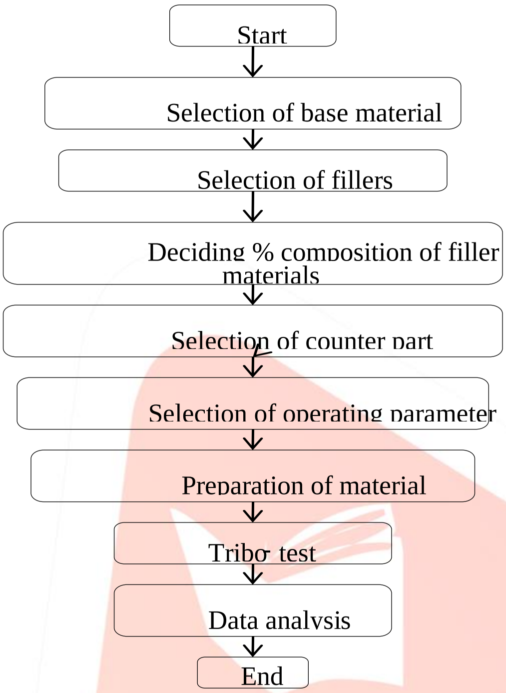

Figure 1: Flowchart of methodology

V. Organization of Dissertation

The dissertation CHAPTER II included the research done and provides the knowledge about the development of new high class polymer and their properties. The CHAPTER III contents the mechanism of wear and friction phenomenon and also provides the data in formation of wear. The CHAPTER IV also provides the information regarding the piston ring tribology. The CHAPTER V polymer composites, its classification and application in various areas. The CHAPTER VI discussed about experimental procedure and various experimental work in detail. CHAPTER VII explained experimental analysis and its outcomes. This dissertation also includes the conclusion and references, certificates and photos drawn during actual project work.

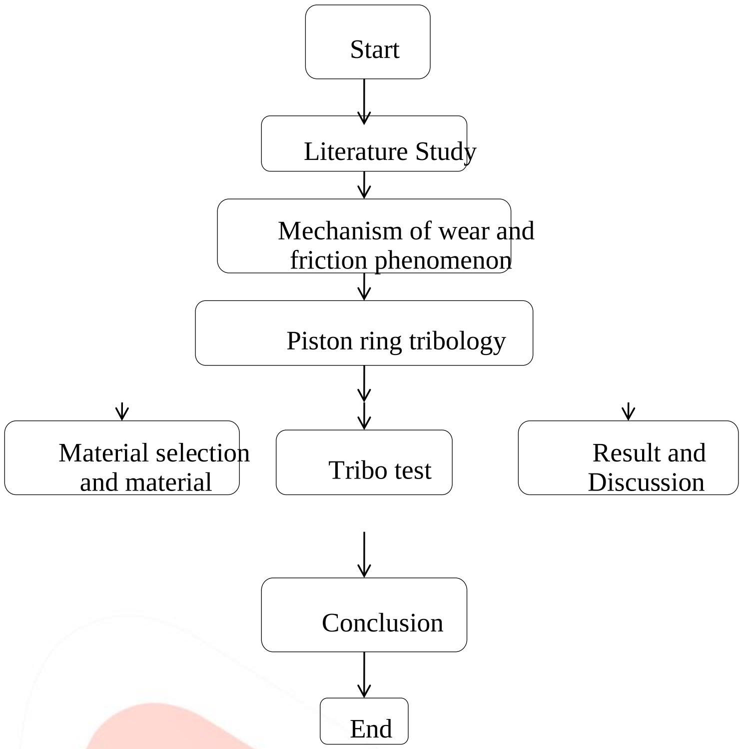

Fig.2: Flowchart of Research Phases

VI. LITERATURE

The purpose of this literature review is to provide background information on the polymer material (PTFE/PEEK/Glass fiber/MoS2/Bronze) which is used for piston ring in non-lubricated compressor. A lot of work has done on PEEK which reports its tribobehaviour as well as mechanical properties. A few of them are summarized in this chapter as follows: Composite materials offer significant advantages over traditional monolithic materials. Modern advanced composites are a success story from the view point of their widespread applications, ranging from tennis rackets to advanced space vehicles. Aggressive research is being carried out worldwide to explore new composites with improved functional properties. This chapter presents the outlines of some of the recent reports published in literature on composites with special emphasis on erosion wear behavior of glass fiber reinforced polymer composites. Polymers and composites are extensively used in tribo-applications such as bearings, gears, bushes, piston rings, rider etc. where liquid lubricants cannot always be used because of various constraints. This chapter presents the outlines of the some of the recently reports published in literature on composites with special emphasis on wear behavior of glass fiber reinforced polymer composites. PEEK is a relatively new technical thermoplastic material with excellent triboproperty. It is semi-crystalline, high performance plastic with very good combination of thermal properties like glass transition temperature 143o, melting temperature 338oc, continuous service 250oc and mechanical properties like, strength, toughness, resistance to creep and fatigue. It is an injection moldable polymer as with other thermoplastic the addition of short fibers such as glass fiber and carbon fiber seems to be promising in its ability to influence certain material properties Several investigations into mechanical behavior of PEEK and its composites have been carried out but very little is known about the wear properties and its composites till now.

VII. Research gaps from Literature Survey

Literature does not clarify the selection & combination process, blending processing temperature of polymer composite.
Many kinds of research have been done on PEEK at room temperature. But very few work has been done on PEEK/PTFE reinforced with glass fiber, MOS2 and Bronze. Inadequate knowledge about PEEK processing and its future application in the area of tribology.

VIII. Need to go for the PEEK/ PTFE Composites

In petro- chemical industry, pharmaceuticals, and coalmines, lubricated compressors are used. The main problem arises in these compressor is the gas contamination, leakage, this increase high temperature and pressure, deform the geometry and degradation of quality of the surface material. Eventually the distorted surface affects the function of the piston rings and results in significant energy losses. the piston ring material should be selected particularly, such that it has small thermal coefficient of expansion, good creep resistance, resistance to chemical attack, high resistance to wear and friction.
To overcome such serious problem some special self-lubricated polymer composite material is used to make the compressor oil-free.

IX. FRICTON AND WEAR

1. Tribology

Tribology is the study of the friction, wear and lubrication of engineering surfaces with a view of understanding surface interactions in detail and then prescribing improvements in given applications. One of the important objectives in tribology is the regulation of the magnitude of frictional force according to whether we require a minimum or a maximum frictional force. This objective can be realized only after a fundamental understanding of the frictional process and is obtained for all conditions of temperature, sliding velocity, lubrication, surface finish and material properties. Years of research in tribology justifies the statement that friction and wear properties of a given material are not its intrinsic properties, but depend on many factors related to a specific application. Quantitative values for friction and wear in the forms of coefficient of friction and wear rate depend on the following basic groups of parameters:

1. The structure of the system, i.e. its components and their relevant properties;
2. The operating variables, i.e. load (stress), kinematics, time and temperature; Mutual interaction of the system's components.

2. Friction

Friction is the resistance to motion, which occurs whenever one body slides over another. Whenever there is contact between two bodies under a normal load W, a friction force is required to initiate and maintain relative motion. This force is called frictional force, F. Three basic facts have been experimentally established:

The frictional force, F, always acts in a direction opposite to that of the relative displacement between the two contacting bodies;

The frictional force, F, is a function of the normal load on the contact,

$$F=\mu FN$$

Where μ = coefficient of friction,

FN = Normal Load.

The frictional force is independent of a nominal area of contact.

These three statements constitute what is known as the laws of sliding friction under dry conditions. Studies of sliding friction have a long history, going back to the time of Leonardo da Vinci. Luminaries of science such as Amon tons, Coulomb and Euler were involved in friction studies, but there is still no simple model which could be used by a designer to calculate the frictional force for a given pair of materials in contact. It is now widely accepted that friction results from complex interactions between contacting bodies which include then effects of surface asperity deformation, plastic gross deformation of a weaker material by hard surface asperities or wear particles and molecular interaction leading to adhesion at the points of intimate contact. A number of factors, such as the mechanical and Physic-chemical properties of the materials in contact, surface topography and environment, determine the relative importance of each of the friction process components. Friction is always associated with heat energy dissipation, and a number of stages can be identified in the process leading to energy losses.

Stage I- Mechanical energy is introduced into the contact zone, resulting in the formation of a real area of contact.

Stage II- Mechanical energy is transformed within the real area of contact, mainly through elastic deformation and hysteresis, plastic deformation, ploughing and adhesion.

Stage III- Dissipation of mechanical energy which takes place mainly through:

thermal dissipation (heat), storage within the bulk of the body (generation of defects, cracks, strain energy storage, plastic transformations) and emission (acoustic, thermal, exo-electron generation).

3. Wear

Wear is commonly defined as the undesirable deterioration of a component by the removal of material from its surface. It occurs by displacement and detachment of particles from surface. The mechanical properties of steel are sharply reduced due to wear. The wear of material may be due to the friction of metals against each other, eroding effect of liquid and gaseous media, Scratching of solid particles from the surface and other surface phenomena. In laboratory tests, wear is usually determined by weight loss in a material and wear resistance is characterized by the loss in weight per unit area per unit time. Wear is commonly defined as the undesirable deterioration of a component by the removal of material from its surface. It occurs by displacement and detachment of particles from surface. The mechanical properties of PEEK are sharply reduced due to wear. The wear of material may be due to the friction of metals against each other, eroding effect of liquid and gaseous media, scratching of solid particles from the surface and other surface phenomena. In laboratory tests, wear is usually determined by weight loss in a material and wear resistance is characterized by the loss in weight per unit area per unit time. Two groups of wear mechanism can be identified; The first comprising those dominated by the mechanical behavior of material. The second comprising those defined by the chemical nature of the materials. Leading wear mechanism, this is usually determined by the mechanical properties and chemical stability of the material, temperature within the contact zone, and operating conditions. Friction and wear share one common feature, that is, complexity. It is customary to divide wear occurring in engineering practice into four broad general classes, namely:

Adhesive Wear

Abrasive Wear

Surface Fatigue Wear

Chemical (Corrosion) Wear

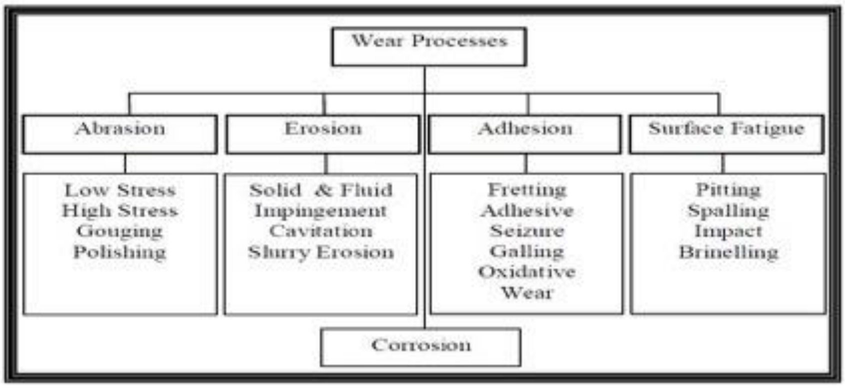

Fig.3 Types of wear mechanisms

X. PISTON RING TRIBOLOGY

Polymers are used for dry sliding components because of their self- lubricating properties. Such polymers exhibit low shear strength and the material in contact deforms readily during sliding. The lubrication action of polymers occurs via material transfer to the counter surface during relative motion. A thin transfer film of polymer material is produced and this film reduces the Coefficient of friction and wear. In process gas and petrochemical industries reliable oil-free compressors are vital, because of the extremely high downtime costs. The majorities of the oil-free compressors used in these industries are of the horizontal reciprocating type and are generally found to be very reliable, the pistons being fitted with compression and bearer rings made from PTFE filled with various inorganic fillers such as carbon, glass fiber, and molybdenum disulphide, or combinations of these. The composite materials consisting of PTFE, carbon, glass fibers, molybdenum disulphide, compounded with epoxy binders, as well as alternative filled plastics such as polyimides and polyphenylene sulphides. The compression rings are normally self-actuating and act as sealing elements between the piston and the cylinder. The bearer rings support the weight of the piston and act so as to prevent the piston contacting the cylinder wall. It is found that the rings initially will wear by up to 0.25 mm and in so doing will transfer a film to the cylinder wall. After the transfer film has been produced the wear rate of the rings is correspondingly reduced to lower levels.

The piston ring-cylinder has a large area of spreading in many engineering fields. One of these is the piston air compressors. This system has a very important role in the case a compressor, to play assuring the energy conversion efficiency. The efficiency of this assembly is based on tightening assuring for a long time of his life with minimal energy consumption. In fact, the efficiency and reliability of this tribo-system are defining for the energy consumption characteristic of the compressor. The sliding contact between the piston ring and the cylinder jacket, this is tighter when the radial contact pressure between the two parts is higher. This, however, increase the friction between the two parts resulting in a number of undesired effect such as wear, higher temperature in the area, higher mechanical energy consumption to overcome the friction. Various cylinder and piston ring used materials as cast iron, alloy and stainless steel, or chrome plating.

For designing a non-lubricated air compressor, the following points have to be considered to ensure the best compressor thermodynamic and dynamic performance as well as adequate piston ring, packing ring, and valve operation life time

Lower piston speed: - Limiting piston speed(<3.5~4.0meters/second)

Lower pressure ratio–This decreases heat of compression

- Lower rotational speed: - less than 900RPM, this ensures the flow capacity and reduced rod loading. It also benefits cylinder cooling, reducing power consumption and discharge temperature, while increasing piston ring life
- Longer piston rod: -allows one or two more piston rings to be mounted, plus rider rings are used to separate the piston and cylinder wall. In this manner, the piston ring sealing efficiency and operational life can be increased.
- Longer piston rod:-In order to further avoid oil carry-over, besides using an oil wiper ring for a self-lubricated compressor, it is necessary to increase the piston rod length by one stroke

A non-lubricated piston has a longer body, more piston rings are mounted, and one or two rider rings are used to separate the cylinder and piston. Normally, PTFE or/and PEEK material rings are used as the sealing rings in CNG gas compressors. These materials have excellent self-lubrication properties under non-oil conditions. The hardness is lower and this allows the rings to touch the cylinder surface to achieve better sealing. The lubrication system only provides lubrication to crankshaft bearings, crankpins, cross-head pin and cross head guides. The piston rings and packing rings are not lubricated by oil, but only by using self-lubricated materials. Compressor major constructive parameters (speed, stroke, cylinder, piston and piston rod) are specially selected and designed to enhance ring life and ensure compressor performance.

As we know that the lubrication system provides direct lubrication to the crank shaft bearings, crankpins, cross head pins, cross head guides, packing rings, and piston rings. Especially the piston rings & packing heats up enormously because of the friction with the piston rod. These high temperatures lead to a reduction of the lifetime of the packing elements. So the task for non-lubricated piston compressors is to reduce influences on the packing, rider rings and the piston rings, that enlarge the possibility of an early wear out and failure of the sealing components Durability of non-lubricated compressors depends on anti-wear ability of the piston rings, and not only anti-wear ability but also sufficient strength of the ring is required at a high pressure condition.

1.Factors Affecting On Piston Ring Life

The major factor which affects PEEK ring life is high temperature; therefore, the discharge temperature of each stage has to be limited. Some new non-lubricated materials can handle higher temperature, e.g. PEEK ring material can be used up to 180°Ctemperature.

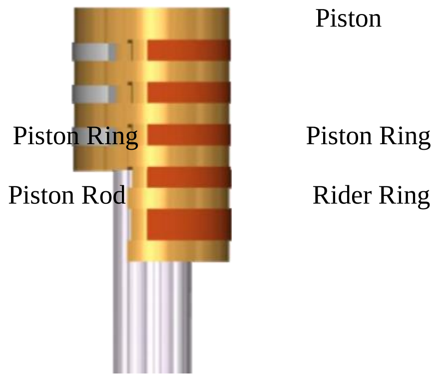

Fig.4 Lubricating and Non lubricating Piston

For the cylinder surface final finish, one might think that it requires much better finish for anon- lubricated compressor than for a lubricated compressor, and continuous operation condition must be very hard for non-lubricated piston ring and packing ring life. However, this is not true. Improved surface smoothness is not necessarily better. Actually, when the surface is too smooth, it is not easy for the PTFE molecule to adhere to the cylinder surface. This is not beneficial for self-lubrication. Normally, the adequate cylinder surface finish is Ra0.25~0.5μm, the sealing ring wear also depends on the compressor operation time. Continuous operation can increase the sealing rings actual operational lifetime. This is because the PTFE molecular film adhering to the surface will continuously provide the lubrication function. Once the compressor shuts down, the film tends to disintegrate. Next time the compressor starts; the lubricating film will be established again.

Piston ring wear rates are dependent on many factors; one of the miss operating temperature. Non lubricated compressor, PTFE materials are used for piston rings, material temperatures should be limited to the range of 130 ~ 145° C; operating above the maximum temperature will shorten the ring life this cannot exceed 4000 h and are not suitable to operate at sealing pressure up to or beyond about 10Mpa and mean piston speed of more than 4.0 m/s. This is the drawback of PTFE Piston ring material needs high anti-wear ability and good sealing ability, which is used for the reason of its lightweight and good thermal conductivity. Kinds of ring materials are chosen from combination of following plastics such as, PTFE, PEEK, Polyimide (PI). In addition to this glass fibers, molybdenum disulphide, bronze these binders, as well as alternative filled plastics such as polyphenylene sulphides used.

XI. APPLICATIONS

Table.1: PEEK comparison to Metals.

STEEL	BRONZE	ALUMINIUM
PEEK has cheaper manufacturing cost	PEEK has better mechanical properties	PEEK has cheaper manufacturing cost
PEEK has fewer leachable	PEEK is harder	PEEK is harder
PEEK has better dry wear properties	PEEK has better wear and friction	PEEK has better wear and friction
PEEK has better chemically resistances	PEEK has better chemically resistances	PEEK has better chemically resistances
PEEK has 83% lower density	PEEK has 85% lower density	PEEK has50% lower density
PEEK has less chemically absorption and release	PEEK has low out-gassing	

Because of its robustness, PEEK is used to fabricate items used in demanding applications, including bearings, piston parts, PS, Columns, compressor plate valves, and cable insulation. PEEK is considered an advanced biomaterial used in medical implants. It is extensively used in the aerospace, automotive, electronic, and chemical process industries. PEEK's mechanical properties at elevated temperatures have led to it being used in at least two varieties of RepRap extruders thermal insulation. This means the rest of the extruder structure can be made of the same material as the object being fabricated without self-destruction. A disadvantage is the high price, which limits its application to high value items.

1.**Polytetrafluoroethylene (PTFE)**

PTFE is a thermoplastic polymer, which is a white solid at room temperature, with a density of about 2.2 g/cm3. According to DuPont, its melting point is 327 °C (621°F). Its mechanical properties degrade gradually at temperatures above −79 °C (−110 °F). PTFE gains its properties from the aggregate effect of carbon-fluorine bonds, as do all fluorocarbons. PTFE has excellent dielectric properties. This is especially true at high radio frequencies, making it suitable for use as an insulator in cables and connector assemblies and as a material for boards used at microwave frequencies. Combined with its high melting temperature, this makes it the material of choice as a high-performance substitute for the weaker and lower melting point polyethylene that is commonly used in low-cost applications. Because of its chemical inertness, PTFE cannot be cross-linked like an elastomer.

Table.2: Physical and mechanical properties of PTFE

Property	Value
Density	2200 kg/m3
Melting point	327 °C
Thermal expansion	135 · 10−6 K−1[12]
Thermal diffusivity	0.124 mm²/s [13]
Young's modulus	0.5 GPa
Yield strength	23 MPa
Bulk resistivity	1018Ω·cm[14]
Coefficient of friction	0.05–0.10
Dielectric constant	ε=2.1,tan(δ)<5(-4)
Dielectric constant (60 Hz)	ε=2.1,tan(δ)<2(-4)
Dielectric strength(1 MHz)	60 MV/m

Therefore, it has no "memory" and is subject to creep. This is advantageous when used as a seal, because the material creep a small amount to conform to the mating surface. However, to keep the seal from creeping too much, fillers are used, which can also improve wear resistance and reduce friction. Sometimes, metal springs apply continuous force to PTFE seals to give good contact, while permitting a beneficially low percentage of creep

XII. Composite

1. Introduction

A combination of two or more materials with different properties, or a system composed of two or more physically distinct phases separated by a distinct interface whose combination produces aggregate properties that are superior in many ways, to its individual constituents. A new material with combination of two or more materials can provide enhanced properties that produce a synergetic effect.

In composite materials there are two constituents one is matrix and other is reinforcement. The constituents which is continuous and present in greater quantity is called matrix. The main functions of the matrix are to holds or bind the fiber together, distribute the load evenly between the fibers, protect the fiber from mechanical and environmental damage and also carry interlinear shear. While the other constituent is reinforcement; its primary objective is to enhance the mechanical properties e.g. stiffness, strength etc. The mechanical property depends upon the shape and dimensions of reinforcement. On the basis of type matrix material, composites can be grouped into three main categories, polymer, metallic and ceramic [25]. While on the basis of reinforcement classification of composite is shown in Figure 5

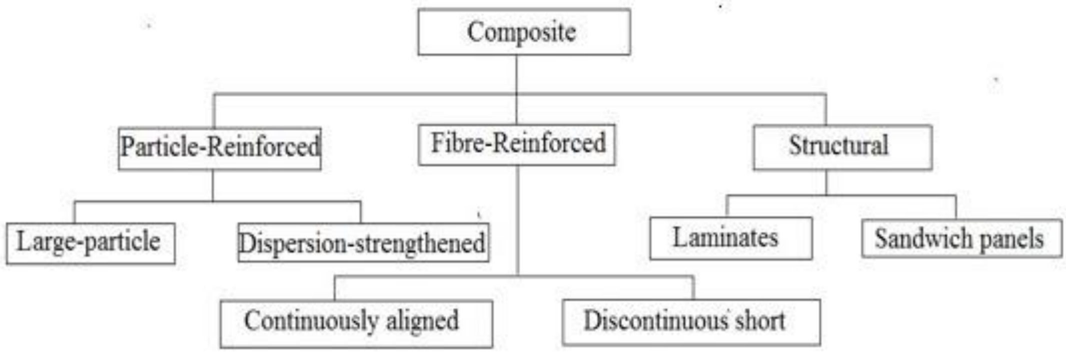

Figure 5 Classification of composite based on the type of reinforcement

The main elements of polymer matrix composite are resin (matrix), reinforcement (e.g. fiber, particulate, whiskers), and the interface between them. The present work deals with the fiber reinforced polymer. FRP"s offers significant advantages, like combination of light weight and high strength to weight ratio and it is way easy to fabricate which is better than many metallic components.

The matrix of FRPs is further classified into-

I. Thermosetting resin
II. Thermoplastic resin

Thermoset resin (e.g. polyester, vinyl esters and epoxy) undergo chemical reaction that cross link the polymer chain and thus connect the entire matrix into three dimensional network due to this they possess high dimensional stability, resistance to chemical solvent, and high temperature resistance. On the other hand, unlike thermoset, curing process of thermoplastic resin (e.g. polyamide, polypropylene, and polyether ether-ketone) is reversible. Their strength and stiffness depends on the molecular weight. They are generally inferior to thermoset in case of high temperature, strength, and chemical stability but are more resistant to cracking and impact damage.

As far we concerned about the reinforcement, there are wide variety of it, like natural fiber (e.g. hemp, kenaf, sisal, coir, jute etc), synthetic fiber (e.g. glass fibers, ceramic etc) and organic fiber (e.g. aramid). Natural fibers are cheap, easily available, and bio-degradable but these advantages are not sufficient to overcome their major drawbacks like moisture absorption, it can be easily attacked by chemicals and has low strength compared to synthetic fibers. Now, in manmade fibers there are two types of fibers,

1. Synthetic fiber
2. Organic fiber

There are numerous types of synthetic fiber such as nylon, acrylic, polyester, glass fiber etc. Now a day most commonly used synthetic fiber is glass fiber. There are also varieties of glass fibers e.g. A-glass, C-glass, D-glass, E-CR glass, E- glass and Glass, among them E-glass and S-glass are most widely and commonly used, in many industries they represent over 90% of reinforcements used. S-glass has higher tensile strength, greater modulus and higher elongation at failure compared to the E-glass, and Glass is mainly used where strength is a primary concern along with weight e.g. airplane fuselage, tail wings of airplane, pipes for carrying aqueous liquid, ship hulls, helicopter blades, tanks and vessels.

Table.3: types of glass fibers

Type	Composition	Characteristics	Application
A-glass	Alkali-lime with little boron oxide	Not very resistant to alkali	When alkali resistance is not a requirement
C-glass	Alkali lime with high boron oxide content	Resistant to chemical attack	When higher chemical resistance required
D-glass	Borosilicate	High dielectric constant	When high dielectric constant is preferred
E-glass	Alumino-borosilicate with alkali oxides less than 1%	Not chloride ion resistant	Mainly for glass reinforced plastics
E-CR-glass	Alumino-lime silicate with alkali oxides less than 1%	High acid resistance	When high acid resistance is required
S-glass	Alumino silicate with high content of MgO	High tensile strength among all types of fibers	Aircraft components, missile casings

E-glass fibers the term "E" stands for electric, which is made from Alumino- borosilicate glass containing oxides of alkali less than 1% by weight, C-glass has high content of boron oxide, whereas S-glass having high content of magnesium oxide with silica and aluminum oxide. The typical composition of different glass fibers is shown in the Table 5.3.1.2 given below.

Table 4 Composition and properties of glass fibers

Compositions (%)	E-glass
SiO2	52.4
Al2O3 + Fe2O3	14.4
CaO	17.2
MgO	4.6
Na2O + K2O	0.8
B2O3	10.6
BaO	-
Properties	
Density (gm/cm3)	2.60
Thermal Conductivity (W/mK)	13
Coefficient of Thermal Expansion (10-6 K-1)	4.9
Tensile Stress (GPa)	3.45
Elastic Modulus (GPa)	76

1 Fiber material

Glass fibers are most common reinforcing agent among various composite materials. Glass fibers are available in the form of woven fabric, chopped strands, long continuous fiber and short discontinuous fiber. In present research work randomly oriented short E-glass fiber is used as reinforcing agent. The average length of E- glass fiber is about 4-5 mm. it is basically an ordinary borosilicate glass containing less than 1% of alkali oxides.

Figure 6 Short E-glass fiber

2: Filler material

2.1: Molybdenum Disulfide

It is widely used as a solid lubricant because of its low friction properties. MoS2 with particle sizes in the range of 1–100 µm is a common dry Few alternatives exist that confer high lubricity and stability at up to 350°C in oxidizing environments. Sliding friction tests of MoS2 using tester at low loads (0.1–2 N) give friction coefficient values of <0.1

In lubricant applications improve reduce wear and improve the friction properties, The formation of Sulphur and molybdenum-rich lubricating film, the sky anti-wear. High vacuum can continue to maintain its excellent resistance to friction and wear properties, its main application is for difficult to maintain equipment, such as: space vehicles, satellites and military fields.

2.2: Bronze

Bronze is an alloy consisting primarily of copper. The addition of other metals (usually tin Bronze is well known for its wear reduction properties and improves thermal conductivity. The melting point of bronze varies is about 950 °C.

XIII. Specimen preparation

Commercially available PEEK of grade 450G fine powder with the average diameter of 100µm was supplied by Victrex. The PTFE powder with the diameter smaller than 60µm was provided by PCEE Textile Kanpur Bronze powder with 10% tin was supplied by Pometon.India ltd. Mumbai. Molybdenum disulfide powder of diameter 100 µm also supplied by Vishal Pharmachem Mumbai. The composite was prepared by compression as well as injection molding. First PEEK, PTFE, Glass fibers, BRONZE and MOS2 were mixed with different proportion for various batches with batch size 100gm for compression molding and 15 gm for injunction molding. For accurate weighing digital weighing balance are used with accuracy 0.0001gm for uniform mixing were done by compounding of raw materials. The samples were prepared with following proportion.

Table 5.6.1: Designation of specimens

Specimen	Compositions
P1	Pure PEEK
P2	PEEK (70%wt) +PTFE (15%wt)+glass fibers(15%)wt
P3	PEEK(65%wt)+PTFE(15%wt)+Glass fibers(15%)wt+MoS2(5%wt)
P4	PEEK(50%wt)+PTFE(15%wt)+Glass fibers(15%)wt+MoS2(5%wt)+Bronze(15%wt)
P5	PEEK(50%wt)+PTFE(15%wt)+Glass fibers(15%)wt+MoS2(5%wt)+Bronze(20%wt)

XIV. EXPECTED Conclusions

The PEEK based composite shows two phases, i) transfer phase and ii) stabilized wear phase.

From the experimental study the following conclusions are drawn.

- Pure PEEK shows high wear rate,
- The addition of glass fibers to PEEK/PTFE improves its wear resistance properties.
- It was also found that the 15% glass fiber reinforced with PEEK/PTFE improving the friction and wear behavior of polymer composite. Also fiber fillers improve the creep resistance and composite strength of the PEEK composite and result enhance wear résistance, it
- MoS2 and Bronze is used as solid lubricant material. These materials easily enter the roughness valley and stably stay on disk. It provides necessary lubrication during sliding. This is helpful to reduce the wear and increase wear life of component.

XV. Acknowledgment

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XVI. REFERENCES

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