SLIDING WEAR BEHAVIOUR OF BIO WASTE REINFORCED POLYMER COMPOSITE

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

Bachelor of Technology
in
Metallurgical and Materials Engineering

By

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CERTIFICATE

This is to certify that the work in this project report entitled "**Sliding wear behaviour of bio waste reinforced polymer composite**" by **Rama Krushna Sabat and Rahul Kumar Rajak** has been carried out under my supervision in partial fulfillment of the requirements for the degree of Bachelor of Technology in Metallurgical and Materials engineering, National Institute of Technology, Rourkela is an authentic work carried out by them under my supervision and guidance.

To best of my knowledge, this work has not been submitted to any other university/institute for the award of any degree or diploma.

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Sliding wear behaviour of bio waste reinforced polymer composite

Abstract

Natural fiber like chicken feather fibers are used as reinforcement in epoxy and polyester matrix composites were prepared. Wear and friction measurement on the short feather fiber reinforced composites have been performed at different loads for different rotational speed of disc. It has been found that the addition of 20% short feather fiber improved the wear resistance than that of pure matrix (epoxy & polyester).Coefficient of friction increased with increase of fiber content and decreased with increase of load. The examination of the worn surfaces of the composites by scanning electron microscopy (SEM) showed that the plastic deformation, plowing and cutting were the main wear mechanisms of the composite and there existed the strain fatigue wear and the abrasive wear features for the composites containing the feather fibers without surface modification and at the higher normal load.

Key words: Feather fiber, sliding wear, SEM, Epoxy, Polyester

CONTENTS

1. INTRODUCTION

1.1 Composites

The material which is composed of two or more different kind of components which are insoluble in each other and maintain their physical phases and they physically and/or chemically separated by a clear-cut interface or inter phases called composites. This gives rise to a new material with a combination of properties of both the phases. It consists of a reinforcing material which is embedded in another phase called matrix. Matrix keeps the fibers in desired location and orientation, prevents their abrasion and helps to transfer load between fibers. Matrix is more ductile than fibers. So it is responsible for toughness of composite. Fiber gives stiffness to the composite. High aspect ratio (length/diameter) permits effective load transfer via the matrix. The reinforcement enhances the mechanical properties of the matrix. It is harder, stronger and stiffer than that of the matrix.

The specific properties of composites are listed below.

- Low Density
- High Specific Strength
- High Specific Modulus
- High Thermal Conductivity
- Good Fatigue Modulus
- Control Of Thermal Expansion
- High Abrasion And Wear Resistance

Composites are needed because modern applications require materials with strange combination of properties like low stiffness, high strength, abrasion and impact resistance.

1.2 Uses of Composites:

- Advanced composites comprise structural materials that have been developed for high-technology applications, such as airframe structures, for which other materials are not sufficiently stiff. In these materials, extremely stiff and strong continuous or discontinuous fibers, whiskers, or small particles are dispersed in the matrix. A number of matrix materials are available, including carbon, ceramics, glasses, metals, and polymers.
- Components fabricated from advanced organic-matrix composites are used extensively on commercial aircraft as well as for military transports, fighters, and bombers. The propulsion system, which includes engines and fuel, makes up a significant fraction of aircraft weight (frequently 50%) and must provide a good thrust-to-weight ratio and efficient fuel consumption.
- Composites consisting of resin matrices reinforced with discontinuous glass fibers and continuous-glass-fiber mats are widely used in truck and automobile components bearing light loads, such as interior and exterior panels, pistons for diesel engines, drive shafts, rotors, brakes, leaf springs, wheels, and clutch plates.
- Composites are also used for leisure and sporting products such as the frames of rackets, fishing rods, skis, golf club shafts, archery bows and arrows, sailboats, racing cars, and bicycles.
- The excellent electrical insulation, formability, and low cost of glass-fiber-reinforced plastics have led to their widespread use in electrical and electronic applications ranging from motors and generators to antennas and printed circuit boards.
- Advanced composites are used in a variety of other applications, including cutting tools for machining of super alloys and cast iron and laser mirrors for outer-space applications. They have made it possible to mimic the properties of human bone, leading to development of biocompatible prostheses for bone replacements and joint implants. In engineering, composites are used as replacements for fiber-reinforced cements and cables for suspension bridges.

1.3 Classification of composites

Matrix Based

- Polymer Matrix Composites
- Metal Matrix Composites
- Ceramic Matrix Composites

Reinforcement Based

- Fiber Reinforced Composites
- Whisker Reinforced Composites
- Particle Reinforced Composites

Now a day's **polymer composite material** are in massive demand for applications in the field of aerospace vehicles, automobile parts, satellites, sports goods, robots, and thermal insulation structures like cryostats for low temperature technology, hydrogen technology tanks, in superconductivity and also in biomedicine for body compatible implants. These materials exhibit exceptionally good characteristics such as low density, high specific strength, good anticorrosion properties, fatigue resistance and low manufacturing costs.

1.4 Fiber Reinforced Polymer matrix composites:

A fiber reinforced composite consists of fibers embedded in a matrix, with distinct interfaces between the two constituent phases. The fibers are usually of high strength and modulus and serve as the principle load carrying members. The matrix is generally more ductile than the fibers; hence it is the source of composite toughness. We can develop different properties using fibers like high strength, toughness, high-temperature strength, thermal stability. They follow the rule of mixtures. FRPs are typically organized in a laminate structure, such that each lamina (or flat layer) contains an arrangement of unidirectional fibers or woven fiber fabrics embedded within a thin layer of light polymer matrix material. The fibers, typically composed of carbon or glass, provide the strength and stiffness. The matrix, commonly made of polyester, Epoxy or Nylon, binds and protects the fibers from damage, and transfers the stresses between fibers. Among FRP's high strength properties, the most relevant features include excellent durability and corrosion resistance. Furthermore, their high strength-to-weight ratio is of significant benefit; a member composed of FRP can support larger live loads since its dead weight does not contribute significantly to the loads that it must bear. Other features include ease of installation, versatility, anti-seismic behavior, electromagnetic neutrality, excellent fatigue behavior and fire resistance.

Fiber reinforced polymer (FRP) composites are being increasingly considered for use in civil infrastructure. They have tremendous applicability to bridge systems ranging from use in seismic retrofit and strengthening of existing structural components, either in all composite form, or in conjunction with conventional construction materials. FRP composites, today, are used in a variety of applications ranging from replacements for steel reinforcement and tendons in concrete, jackets for retrofit of columns, and externally bonded reinforcement for the rehabilitation of deteriorating structural systems to use in all composite structures such as building frames and even bridge decks.

However, like most structural materials, FRPs have a few drawbacks that would create some hesitancy in civil engineers to use it for all applications: high cost, brittle behavior, susceptibility to deformation under long-term loads, UV degradation, photo-degradation (from exposure to light), temperature and moisture effects, lack of design codes, and most importantly, lack of awareness.

1.5 Constituents of FRP Composites

The fibers are usually fiberglass, carbon, or aramid fiber.

The polymer may be

Thermosetting -- Epoxy resin, polyster

Thermoplastics – Amorphous – polysalphones

Semi crystalline – PEEK (Poly Ether Ether Ketone)

Crystalline - Nylon

Additives and modifier ingredients expand the usefulness of polymers, enhance their processability or extend product durability.

1.6 Bio Fibers:-

Bio fibers have recently attracted the attention of scientists and technologists because of the advantages that these fibers provide over conventional reinforcement materials, and the development of bio fiber composites has been a subject of interest for the past few years. These bio fibers have low-cost with low density and high specific properties. These are biodegradable and nonabrasive, unlike other reinforcing fibers. Also, they are readily available and their specific properties are comparable to those of other fibers used for reinforcements. However, certain drawbacks such as incompatibility with the hydrophobic polymer matrix, the tendency to form aggregates during processing, and poor resistance to moisture limit the potential of bio-fibers to be used as reinforcement in polymers [**1–4**].

Another important aspect is the thermal stability of these fibers. These fibers are lingo-cellulosic and consist of mainly lignin, hemi-cellulose, and cellulose. The cell walls of the fibers undergo pyrolysis with increasing processing temperature and contribute to char formation. These charred layers help to insulate the lingo- cellulosic from further thermal degradation. Since most thermoplastics are processed at high temperatures, the thermal stability of the fibers at processing temperatures is important.

Thus the key issues in development of bio reinforced composites are

(i) Thermal stability of the fibers,

(ii) Surface adhesion characteristics of the fibers, and

(iii) Dispersion of the fibers in the case of thermoplastic composites.

1.7 Types of Bio Fibers:-

Bio fibers are grouped into three types: seed hair, bast fibers, and leaf fibers, depending upon the source. Some examples are cotton (seed hairs), ramie, jute, and aflax (bast fibers), and sisal and abaca (leaf fibers). Of these fibers, jute, ramie, flax, and sisal are the most commonly used fibers for polymer composites. On the basis of the source which they are derived from bio fibers can also be grouped as:

- Fibers obtained from plant/vegetable (cellulose: sisal, jute, abaca, bagasse)
- Fibers obtained from mineral (minerals: asbestos)
- Fibers derived from animal species (sheep wool, goat hair, cashmere, rabbit hair, angora fiber, horse hair)
- Fibers from bird / aqueous species.

Numerous reports are available on the bio fiber composites. The research works on development of bio/bio-fiber reinforced polymer composites have been extensively reviewed also. Many researchers have been conducted to study the mechanical properties, especially interfacial performances of the composites based on bio fibers due to the poor interfacial bonding between the hydrophilic bio fibers such as sisal, jute and palm fibers and the hydrophobic polymer matrices.

1.8 Bio Fiber Reinforced Composites:

A bio-composite is a material formed by a matrix (resin) and a reinforcement of bio fibers (usually derived from plants or cellulose). With wide-ranging uses from environment-friendly biodegradable composites to biomedical composites for drug/gene delivery, tissue engineering applications and cosmetic orthodontics, they often mimic the structures of the living materials involved in the process in addition to the strengthening properties of the matrix that was used but still providing biocompatibility. Bio-composites are characterized by the fact that the bolsters (glass or carbon fiber or talc) are replaced by bio fiber (wood fibers, hemp, flax, sisal, jute...)These bio/bio-fiber composites (bio-Composites) are emerging as a viable alternative to glass-fiber reinforced composites especially in automotive and building product applications. The combination of bio-fibers such as kenaf, hemp, flax, jute, henequen, pineapple leaf fiber, and sisal with polymer matrices from both nonrenewable and renewable resources to produce composite materials that are competitive with synthetic composites requires special attention.

Bio fiber–reinforced polypropylene composites have attained commercial attraction in automotive industries. Bio fiber-polypropylene or bio fiber-polyester composites are not sufficiently eco-friendly because of the petroleum-based source and the non-biodegradable nature of the polymer matrix. Using bio fibers with polymers based on renewable resources will allow many environmental issues to be solved. By embedding bio-fibers with renewable resource–based biopolymers such as cellulosic plastics; polylactides; starch plastics; polyhydroxyalkanoates (bacterial polyesters); and soy-based plastics, the so-called green bio-composites are continuously being developed.

1.9 Mechanical properties of bio fibers:-

FIBER	SPECIFIC GRAVITY	TENSIL STRENGTH(MPa)	MODULOUS(GPa)	SPECIFIC MODULOUS
Jute	1.3	393	55	38
Sisal	1.3	510	28	22
Flax	1.5	344	27	50
Sunhemp	1.07	389	35	32
Pineapple	1.56	170	62	40
Glass fiber-E	2.5	3400	72	28

Table 1 Mechanical Properties of Bio Fibers

(Source [Ref. **5**]: Advances in Polymer Technology, Vol. 18, No. 4, 351–363,1999)

As can be seen from Table 1, the tensile strength of glass fibers is substantially higher than that of bio fibers even though the modulus is of the same order. However, when the specific modulus of bio fibers (modulus/specific gravity) is considered, the bio fibers show values that are comparable to or better than those of glass fibers. These higher specific properties are one of the major advantages of using bio fiber composites for applications wherein the desired properties also include weight reduction.

2.0 Literature Survey

Composite materials offer exciting 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 outlines some of the recent reports published in literature on natural/bio-fiber reinforced composites and on the wear behavior polymer composites

Natural fiber reinforced polymer composites have raised great attention and interest among materials scientists and engineers in recent years due to the considerations of developing an environmental friendly material and partly replacing currently used glass or carbon fibers in fiber reinforced composites [**5**]. They are high specific strength and modulus materials, low priced, recyclable and are easily available. Some experimental techniques, from micro scale to macro scale, such as single fiber pull-out test, single fiber fragmentation test, short beam shear test etc. have been employed to evaluate the interfacial performances of this kind of composites. It is known that natural fibers are non-uniform with irregular cross sections which make their structures quite unique and much different with man-made fibers such as glass fibers, carbon fibers etc. Saheb and Jog [**6**] have presented a very elaborate and extensive review on the reported work on natural fiber reinforced composites with special reference to the type of fibers, matrix polymers, treatment of fibers and fiber-matrix interface. Many researchers have been conducted to study the mechanical properties, especially interfacial performances of the composites based on natural fibers due to the poor interfacial bonding between the hydrophilic natural fibers such as sisal, jute and palm fibers and the hydrophobic polymer matrices. Worldwide laboratories have worked on this topic [**7-10**]**.** But reports on composites using fibers like poultry feathers are rare.

Materials derived from chicken (poultry) feathers can also be used advantageously as the reinforcing materials in polymer matrix composites. Such applications can potentially consume the huge quantity of feathers produced annually as a by- product of various poultry units worldwide. Chicken feathers are approximately 91% protein (keratin), 1% lipids, and 8% water [**13**]**.** The amino acid sequence of a chicken feather is very similar to that of other feathers and also has a great deal in common with reptilian keratins from claws [**14**]. The sequence is largely composed of cystine, glycine, proline, and serine, and contains almost no histidine, lysine, or methionine [**15**].

The slide wear of materials caused by sliding of two surfaces is one of several forms of material degradation generally classified as wear.

Kishore, P. Sampathkumaran, S. Seetharamu, P. Thomas and M. Janardhana studied the comparative performance of glass–epoxy (G–E) composites, having rubber in one instance and graphite of two differing levels in epoxy matrix resin in the other, during sliding in pin-on-disc type set up under varying load and sliding velocities is reported in this investigation. Besides conventional weighing, determination of coefficient of friction (μ) and examination of the worn surface features by scanning electron microscope (SEM) were undertaken to have an overall picture of the tribological behaviour of the filled composites.

They concluded that for increased load and sliding velocity situations, higher wear loss was recorded. In case of rubber-bearing samples, the coefficient of friction values show an increasing trend with a rise in load and a decrease in their values for increase in velocity. The coefficient of friction increases with increase in load for a fixed velocity in higher graphite bearing samples. However, G–E composite having either lower or higher amount of graphite shows, respectively, either a decrease or increase in coefficient of friction with an increase in sliding velocity for a fixed load. Thus, the higher graphite bearing G–E composite records lower coefficient of friction for any combination of load and velocity. These are explained on the basis of frictional drag forces and formation of graphite film on the surface. He concluded that the response to tribo situations in G–E polymer composite system is dependent on filler type as well as its amount. Between the two fillers attempted in this work, graphite-bearing ones exhibit lower wear loss, whose value drops down further when the content of the filler in the composite is raised.As regards the coefficient of friction, no one common trend could be observed. This is partly due to the response of the fillers being different. The rubber-bearing samples being elastic offer a different tribo situation compared to graphites, which are prone to basal slip. The amount of this material on the tribo surface also has a bearing on the test parameters recorded. The work points to the need to employ a hybrid-filled G–E system, where the differing responses arising from rubber and graphite could well be tapped for applications requiring low wear loss accompanied by moderate values of friction.

Haşim Pıhtılı’ and Nihat Tosun studied the wear behaviour of a glass-fibre-reinforced composite and plain polyester resin are experimentally investigated for speeds of 500 and 710 rpm and at two different loads of 500 and 1000 g by the use of a block-on-disk wear tester. Wear in the experiments was determined as weight loss. The weight losses were measured after sliding distances of 235.5, 471, 706.5, 942, 1177.5, 1413, 1648.5 and 1884 mm.

They concluded that the wear resistance of the fibreglass-reinforced composite specimens is much more than the plain polyester.The load applied on the specimens is more effective on the wear behaviour of the specimens than the speed. Because of increasing of temperature together with the applied load, the thickness of the brittle layer on the specimen surface has increased. These layers have broken out from the specimen surface. The broken pieces have increased the wear by acting as an abrasive medium between the shaft and surface.

S. C. Sharma, B. M. Girish, D. R. Somashekar, B. M. Satish and Rathnakar Kamath studied the unlubricated sliding wear behaviour of zinc–aluminium (ZA) alloy composites reinforced with zircon particles of size 30–50 μm. The content of zircon in the alloy was varied from 1–5% in steps of 2 wt.%. The liquid metallurgy technique was used to fabricate the composites. A pin-on-disc wear testing machine was used to evaluate the wear rate, in which a hardened EN24 steel disc was used as the counterface. The results indicated that the wear rate of the composites was lesser than that of the matrix alloy and it further decreased with the increase in zircon content. However, the material loss in terms of wear rate and the wear volume increased with the increase in load and sliding distance, respectively, both in the case of composites and the alloy. Increase in the applied load increased the wear severity by changing the wear mechanism from abrasion to particle cracking induced delamination wear. It was found that with the increase in zircon content, the wear resistance increased monotonically.

They concluded that the zircon reinforced composites exhibited reduced wear rate than the unreinforced ZA-27 alloy specimens. The wear rate of the composites as well as the matrix alloy increased with the increase in load applied. However, the wear rate of the composites decreased with increasing zircon content. The composite specimens exhibited abrasion wear at low loads, while at high loads it is delamination wear that was dominant. SEM micrographs of the composite specimens tested at high loads revealed severe plastic deformation and surface damage leading to delamination wear.

S.A.R. Hashmi, U.K. Dwivedi and Navin Chand studied for friction and sliding wear behaviour at different applied loads and graphite concentrations for graphite modified polyester–cotton composites.They concluded

(a)Incorporation of cotton fibres in the unsaturated polyester resin improves the structural integrity of material under sliding wear condition. The addition of graphite in the cotton–polyester composites further enhances the capability of material to withstand against sliding wear test.

(b) The specific wear rate of polyester resin decreased with the cotton fibre reinforcement. The composites exhibited further reductions in specific wear rate against the normal load in the specimens those containing graphite.

(c) The coefficient of friction increased with the addition of cotton fibre in the polyester resin and decreased on increasing graphite content in the composite. The graphite in the composite provided the lubricating effect under the dry sliding conditions against the steel disc.

(d) Significant reduction in the contact-surface-temperature was observed on addition of graphite in cotton–polyester composites.

Jin Tong, R. D. Arnell and Lu-Quan Ren studied dry sliding wear behaviour of bamboo (*Phyllostachys pubescens*) against a grey iron (HT200) was examined on a block-on-ring machine. The wear volume of bamboo was a function of the normal load, the sliding velocity and the relative orientation of bamboo fibres with respect to the rubbing surface.

They concluded that the wear volume increased with the normal load and sliding velocity. The normal-oriented specimens (N-type) gave better wear resistance than the parallel-oriented ones (P_S- and P_I-type), and the outside surface layer (P_S-type) gave better resistance than the inner later (P_I-type). Material transfer from bamboo to the counterface took place during the rubbing process for the three types of specimens. The predominant wear mechanisms were adhesion, microcracking and microploughing–microcutting for the P_S- and P_I-type, and adhesion and microcracking for the N-type.

J. Aurrekoetxea, M. Sarrionandia and X. Gómez compared friction coefficient, wear rate and wear micromechanism of wood reinforced polypropylene (WPC), pine wood and polypropylene (PP).They concluded

(a) WPC has higher density that PP and wood, and it is due to the fact that in WPC the cellular structure of wood is collapsed or PP filled.

(b) WPC and wood have very similar μ, and PP presents the higher one. The higher strength and the lower temperature rise of the WPC, when compared with neat PP, stop the ploughing of the counterbody, and the resulting smaller contact area is the origin of the lower friction of coefficient. The increase of μ in the earlier stages of the WPC test is associated to the neat PP skin-layer, and the following stabilised value is achieved when this skin is eliminated and counterbody is in contact with PP matrix and wood reinforcement of WPC.

(c) The wear rate of WPC is the lowest, the one of neat wood is 10 times higher and that of PP is the highest. The wear mechanism for PP is a combination of plastic flow and melting phenomenon, which are at the origin of its highest wear rate. For wood, the microfisuration and delamination induced by deformation are the main wear micromechanism. In WPC the wear mechanism of the wood reinforcement are different to those of neat wood, since the collapsed or PP-filled wood fibers into the WPC which reduces the buckling/microfisuration/delamination micromechanisms inherent to the cellular structure of wood.

There are also several reports in the literature which discuss the slide wear behavior of fibrous composites. These papers mainly showed, however, only the slide wear behavior and performance to slide wear damage.

Hence keeping the above in view, the present piece research work is undertaken aiming at processing poultry feather reinforced polymer composite and to evaluate the physico mechanical properties at different conditions.

3.0 Experimentation

The objective of the present work is outlined as follows:

1 Fabrication of a series of matrix composites reinforced with
   - Untreated Poultry feather

2 Surface analysis of the composites

3 Mechanical characterization of these composites

4 Study of tribological behavior (sliding wear) of these composites

3.1 Composite fabrication

Epoxy resins and polyester resins are used as matrix in different type of composites. These materials are noted for their versatility, but their relatively high cost has limited their use. High resistance to chemicals and outstanding adhesion, durability, and toughness has made them valuable as coatings. Because of their high electrical resistance, durability at high and low temperatures, and the ease with which they can be poured or cast without forming bubbles, epoxy resin plastics are especially useful for encapsulating electrical and electronic components. Epoxy resin adhesives can be used on metals, construction materials, and most other synthetic resins. They are strong enough to be used in place of rivets and welds in certain industrial applications.

Epoxy or poly-epoxide is a thermosetting peroxide polymer that polymerizes and cross links when mixed with a catalyzing agent or "hardener". Most common epoxy resins are produced from a reaction between epichlorohydrin and bisphenol-A. Unsaturated isophthalic polyester resin is used as polyester resin, 2%cobalt nephthalate (as accelerator) is mixed thoroughly in isophthalic polyester resin and then 2% methyl-ethyl-ketone-peroxide (MEKP) as hardener is mixed in the resin prior to reinforcement.

a) With reinforcement of poultry feather

The chicken feathers collected from poultry units are cleaned with a polar solvent, like ethanol, and are dried. The quills are removed and the short fibers (10-15 mm length) are obtained. To prepare the composite cylinders, these fibers in pre-determined weight proportion (20%) are reinforced with random orientation into the epoxy resin and polyester resin. A cylinder of size (15mm diameter X 80mm) is thus cast. Then the sample is removed from the test tube by breaking it. After that the sample is subjected to belt polishing to produce a given diameter of 12mm. Specimens of suitable dimension are cut using a hex saw and polished both of its surface(top as well as bottom)for physical characterization.

3.2 Density and void fraction

The theoretical density of composite materials in terms of weight fraction can easily be obtained as for the following equations given by Agarwal and Broutma .

$$\rho_{ct} = \frac{1}{\left(\frac{Wf}{\rho f}\right)+\left(\frac{Wm}{\rho m}\right)} \qquad [1]$$

Where, W and ρ represent the weight fraction and density respectively. The suffix f, m and ct stand for the fiber, matrix and the composite materials respectively. The actual density (ρ_{ce}) of the composite, however, can be determined experimentally by simple water immersion technique. The volume fraction of voids (V_{ct}) in the composites is calculated using the following equation:

$$V_{ct} = \frac{\rho ct - \rho ce}{\rho ct} \qquad [2]$$

3.3 Flexural strength

The short beam shear (SBS) tests are performed on the composite samples at room temperature to evaluate the value of flexural strength (FS). It is a 3-point bend test, which generally promotes failure by inter-laminar shear. The SBS test is conducted as per ASTM standard (D2344-84) using the same UTM. Span length of 40 mm and the cross head speed of 1 mm/min are maintained. The flexural strength (*F.S.*) of any composite specimen is determined using the following equation.

$$F.S = \frac{3PL}{2bt^2} \qquad [3]$$

Where, *L* is the span length of the sample. P is the load applied; b and t are the width and thickness of the specimen respectively.

3.4 Mechanical properties of composite:

In the present investigation the reinforcement of poultry feather in short form and in particulate form into epoxy and polyester resin has not shown any encouraging results in terms of mechanical properties. The flexural strength of the composite is measured to be 70.45 MPa where as that of neat epoxy is about 70 MPa. The incorporation of feathers has not caused any significant improvement in the flexural strength as well. However, there enforcement has caused a reduction of about 13% in the composite density which leads to improvement in the strength to weight ratio. The density of the composite is measured to be 0.97 gm/cc (with void fraction of 1.2%) which is less than the density of neat epoxy (1.12 gm/cc)

3.5 Wear

A progressive loss of material from its surface is called wear. It is a material response to the external stimulus and can be mechanical or chemical in nature. Wear is unwanted and the effect of wear on the reliability of industrial components is recognized widely; also, the cost of wear has also been recognized to be high. Systematic efforts in wear research were started in the 1960's in industrial countries. The direct costs of wear failures, i.e., wear part replacements, increased work and time, loss of productivity, as well as indirect losses of energy and the increased environmental burden, are real problems in everyday work and business. In catastrophic failures, there is also the possibility of human losses. Although wear has been extensively studied scientifically, in the 21st century there are still wear problems present in industrial applications. This actually reveals the complexity of the wear phenomenon.

3.6 Slide wear Test Apparatus

The set up used in this study for the wear test is capable of creating reproducible sliding wear situations for accessing slide wear resistance of the prepared composite samples. It consists of a pin on disc, loading panel and controller.. The slide wear of poultry feather (short fiber and particulate form) are reinforced in epoxy and polyester matrixes are carried out with different load by varying speed.

Fig:- (A)

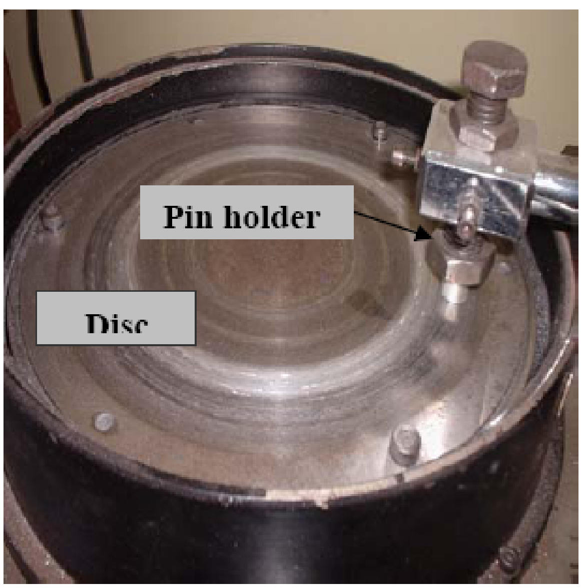


Fig:-(B) Pin on disc

Fig:- (C) Loading panel

Fig: (A-C) Experimental set up

To evaluate the performance of these composites under dry sliding condition, wear tests will be carried out in a pin-on-disc type friction and wear monitoring test rig as per ASTM G 99. The counter body is usually a disc made of hardened ground steel. The specimen is held stationary and the disc is rotated while a normal force is applied through a lever mechanism. Sliding Wear is initially adhesive and later abrasive in nature. It is measured in terms of specific wear rate and volumetric wear rate.

The specific wear rate is defined as the volume loss of the specimen per unit sliding

$$\mathbf{W_s = W_v/(V_s * F_n)}$$

where m is the mass loss in the test duration (g), is the density of the composite (g/mm3), t is the test duration (s), Vs is the sliding velocity (m/s), and Fn is the average normal load (N).distance per unit applied normal load.

Volumetric wear rate is the volume loss per unit time

$$\mathbf{W_v = mass\ loss/(density * time)}$$

Factors affecting sliding wear

- Sliding velocity
- Sliding distance
- Normal Load
- Counter-body

Sequential wear mechanism

- As the sliding proceeds, with increase in applied load and/or sliding velocity, the polymer softens due to frictional heat generation.

- Then there is a plastic flow of the matrix material in the sliding direction causing surface deformation.
- Then the fragmented fibers/ filler particles, which normally have sharp edges, easily tear the matrix and gradually get aligned along the sliding direction.
- These particles by virtue of their size, shape, brittleness, and high harness influence modify the wear behavior of the composites. Longer duration of sliding results in formation of wear debris of different sizes and shapes.

4. Results and discussions

4.1 Wear Studies:-

The slide wear of poultry feather (short fiber and particulate form) are reinforced in epoxy and polyester matrixes are carried out with different load by varying speed. It is found that the volume loss of different composites as a function of time is shown in Figure 4.3. It can be seen that reinforcement of short feather fibers reduces the wear rate of the epoxy resin quite significantly.

Slide wear behavior of polyester and epoxy matrix composites are studied and presented in Fig (1-9).Fig (1-9)represents the volumetric loss with time.

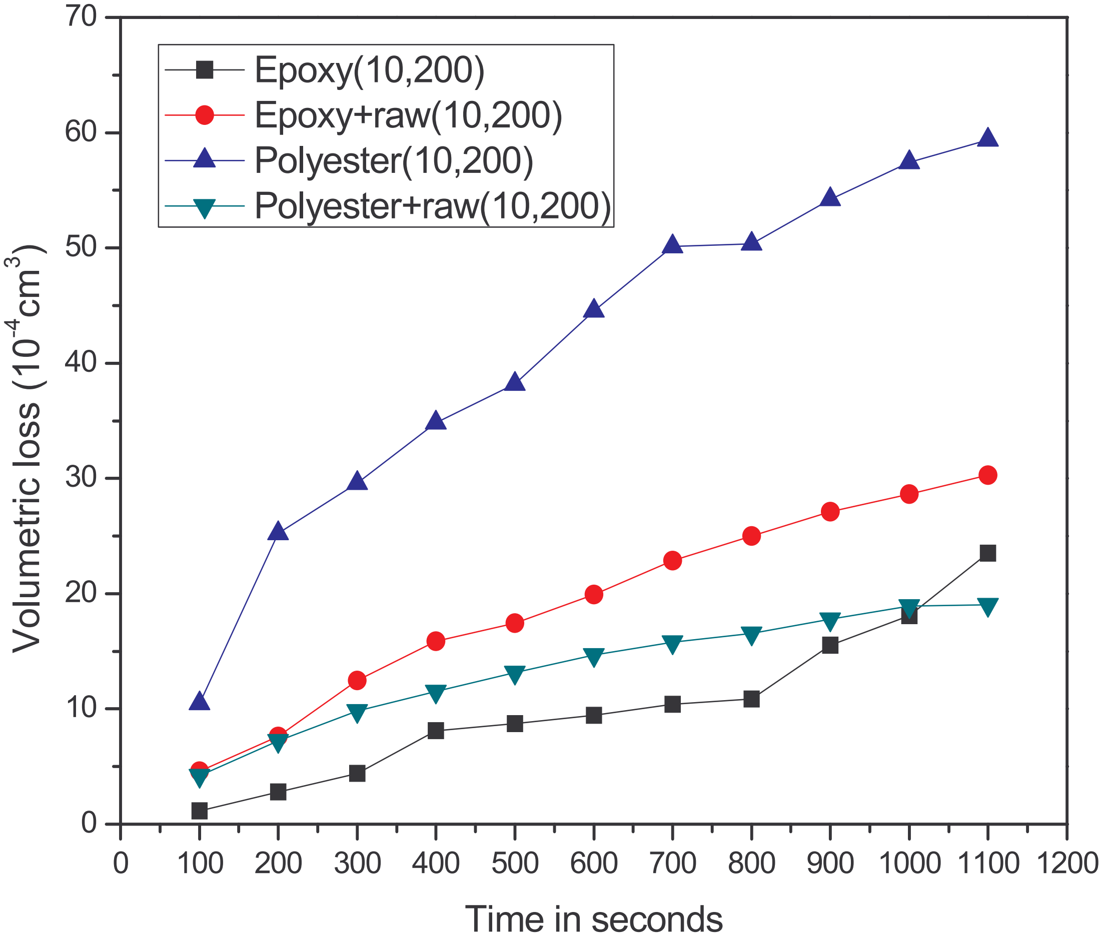


Figure:-1

The above figure shows that neat epoxy has greater resistant to slide wear than feather reinforced epoxy composite. Polyester has least resistant to slide wear among all. Feather reinforced polyester composite has maximum resistant to wear after 1000 seconds.

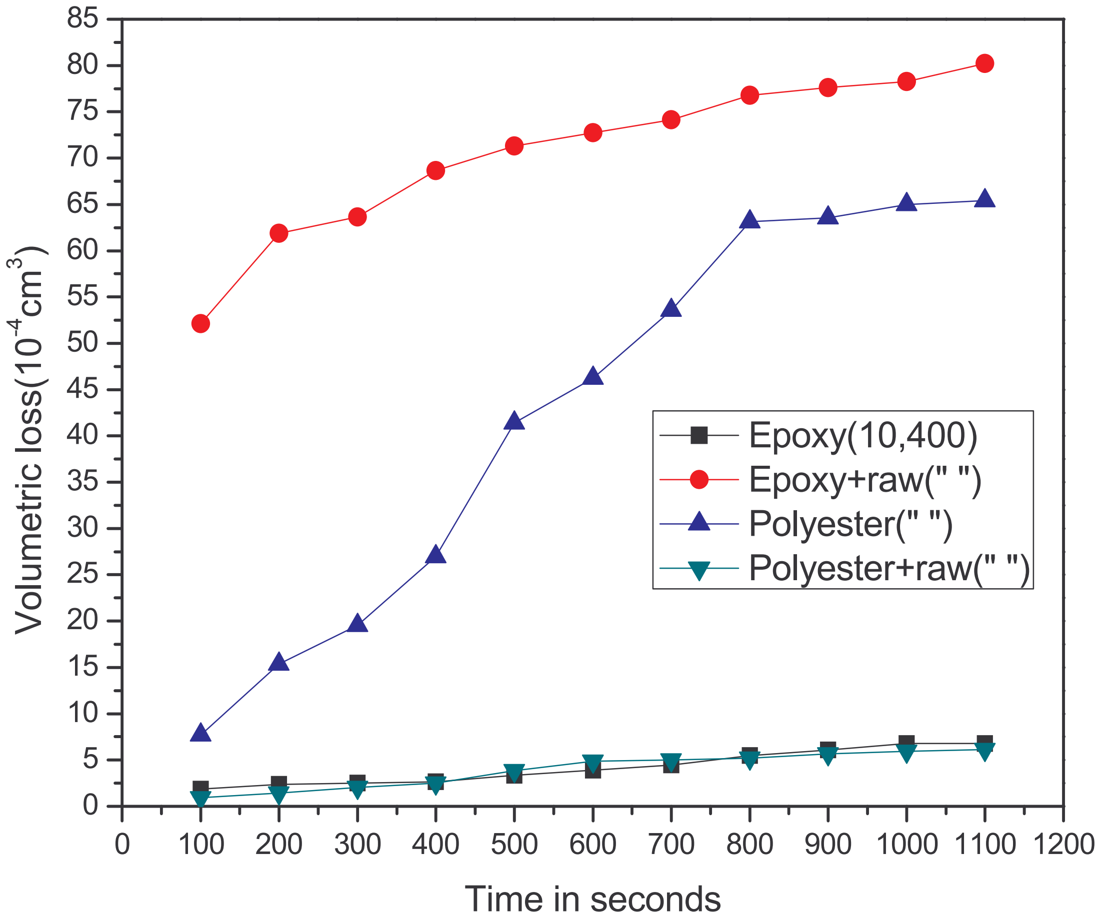


Figure:-2

From the above figure it is cleared that feather reinforced polyester composite has least resistant to wear under same load and same rpm among other materials and it tends acquire constant value after some time. The neat polyester show almost increasing volumetric wear exponentially.

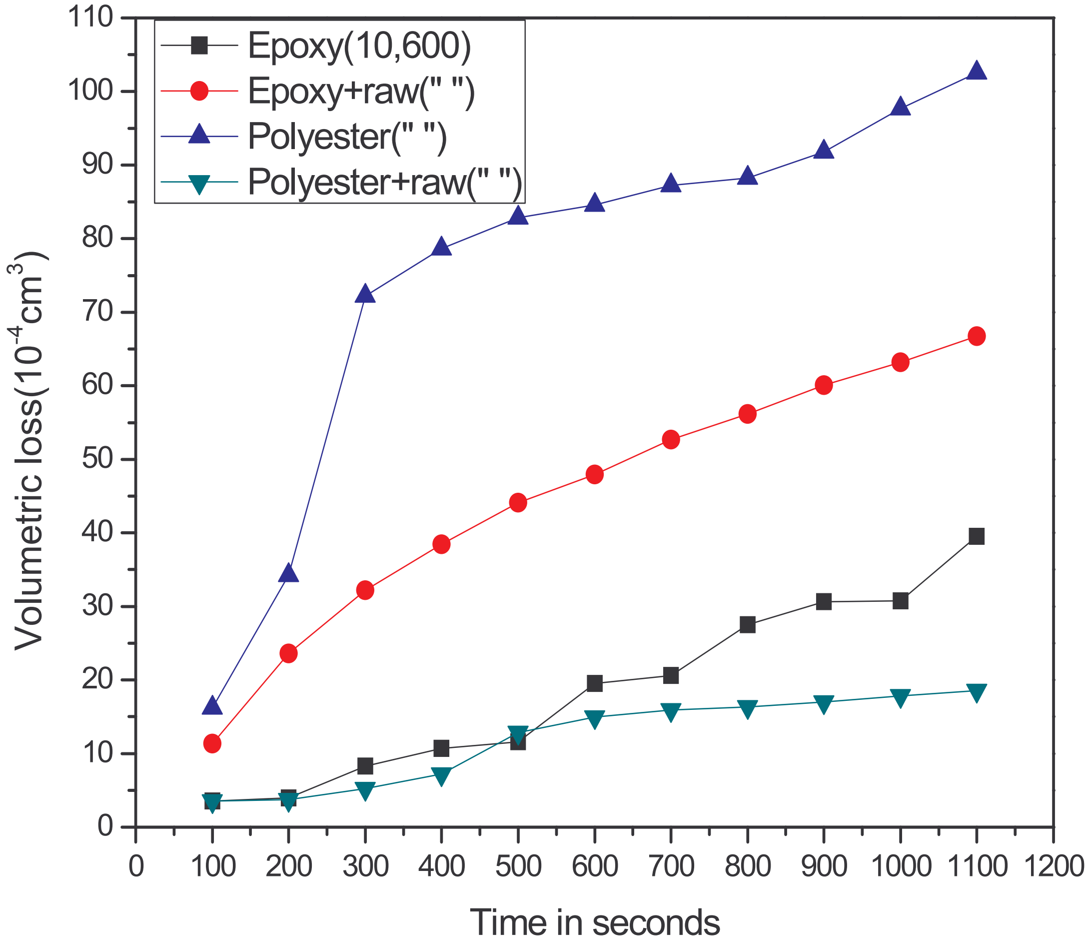


Figure:-3

From the above fig. it is cleared that the volumetric wear loss increases suddenly from 100 to 300 seconds in case of polymer. But the epoxy reinforced feather composite follows a parabolic path.

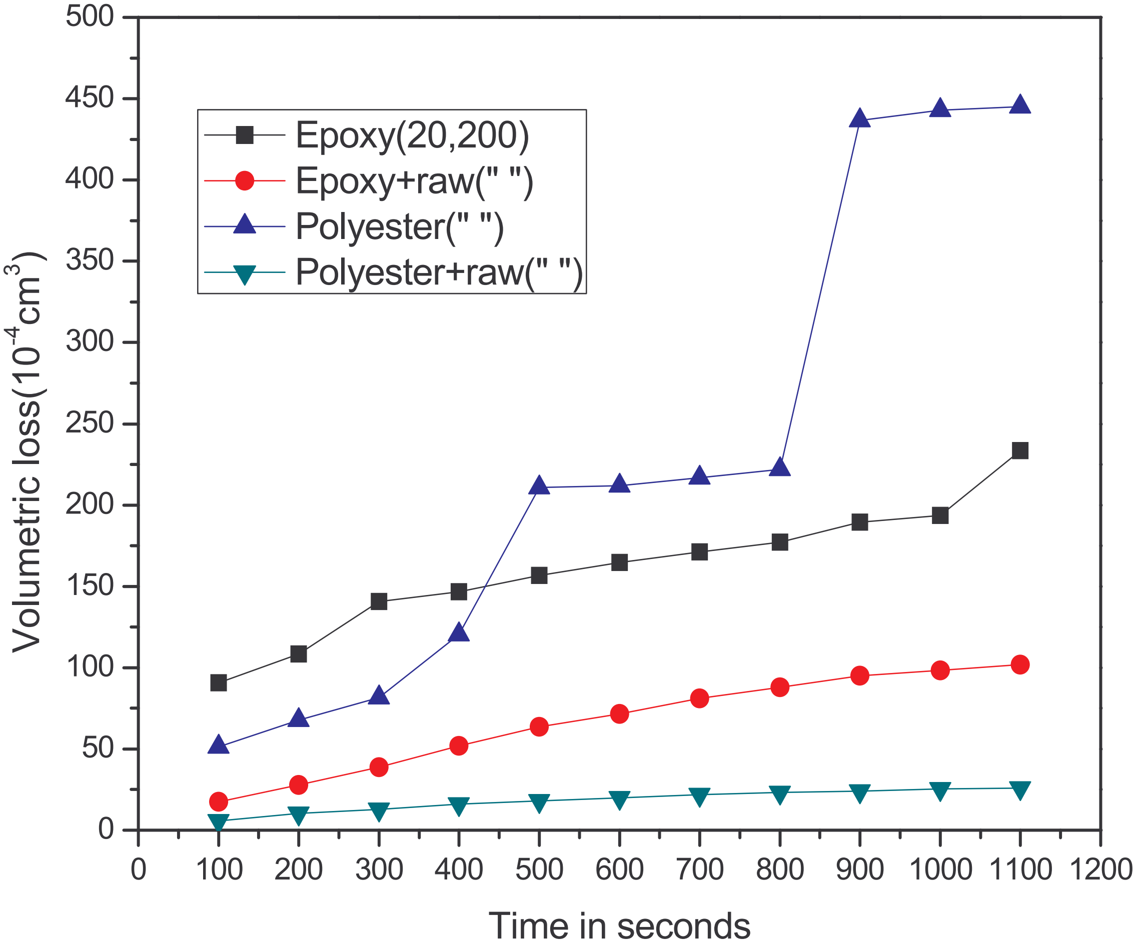


Figure:-4

The above fig. shows that at higher load with same rpm the feather reinforced epoxy composite has greater slide wear resistant than neat epoxy and it follows the parabolic path.

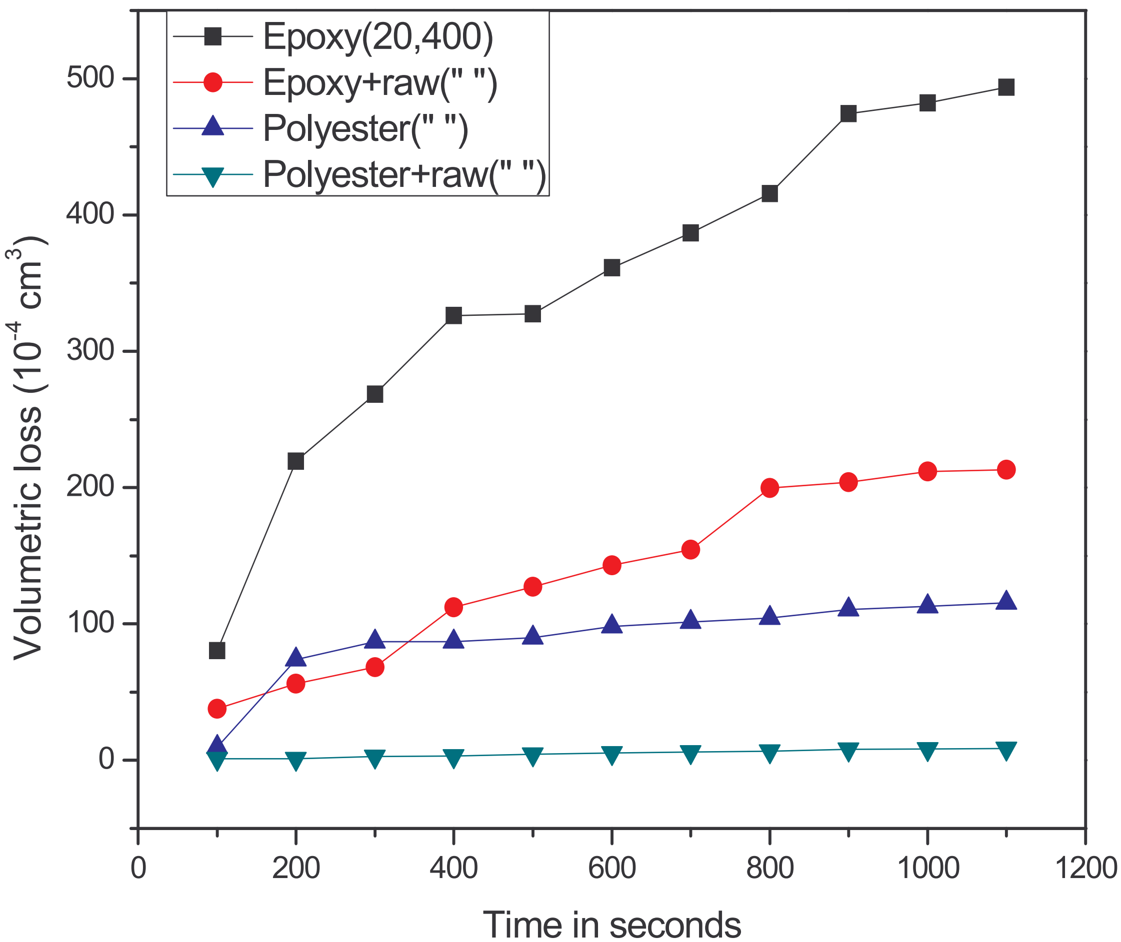

Epoxy(20,400)
Epoxy+raw(" ")
Polyester(" ")
Polyester+raw(" ")
Volumetric loss (10^{-4} cm^3)
Time in seconds
0
100
200
300
400
500
0
200
400
600
800
1000
1200

Figure:-5

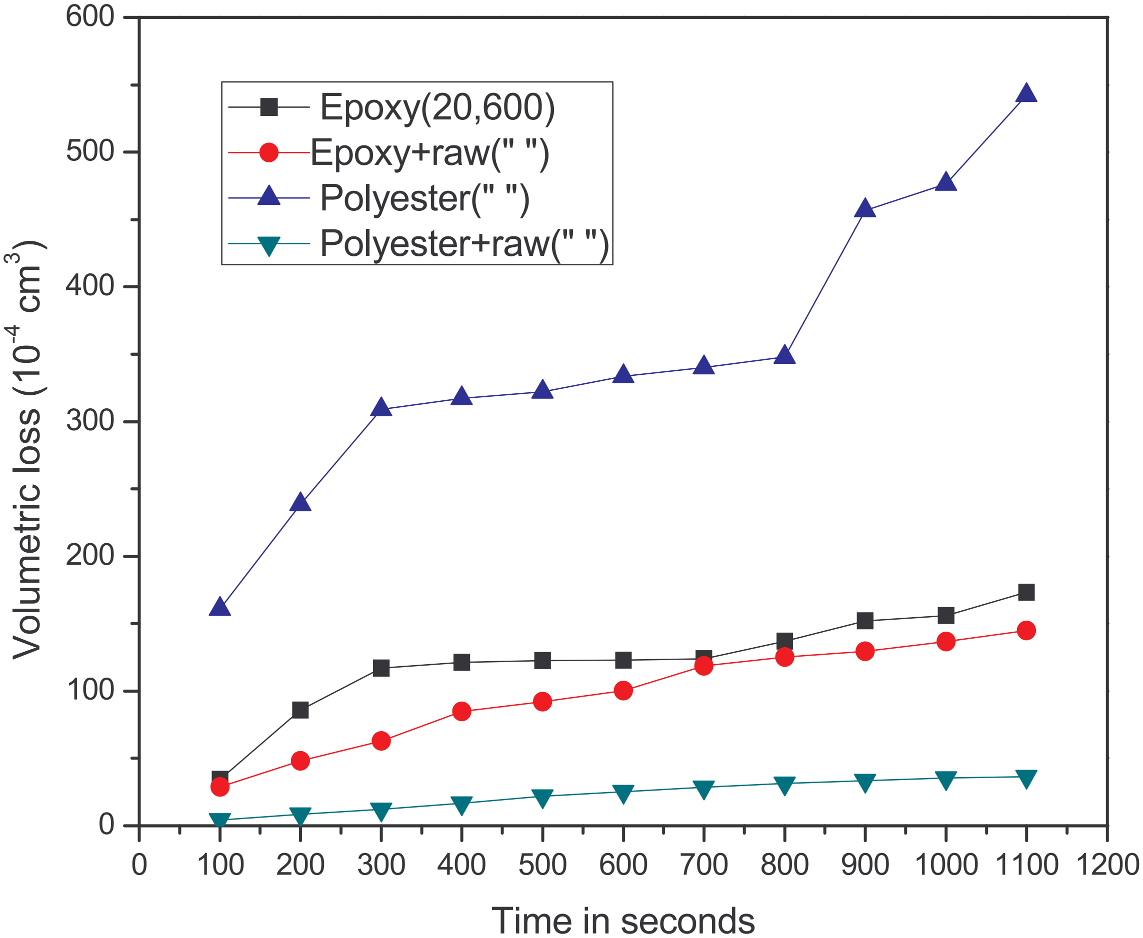

Epoxy(20,600)
Epoxy+raw(" ")
Polyester(" ")
Polyester+raw(" ")
Volumetric loss (10^{-4} cm^3)
Time in seconds
0
100
200
300
400
500
600
700
800
900
1000
1100
1200

Figure:-6

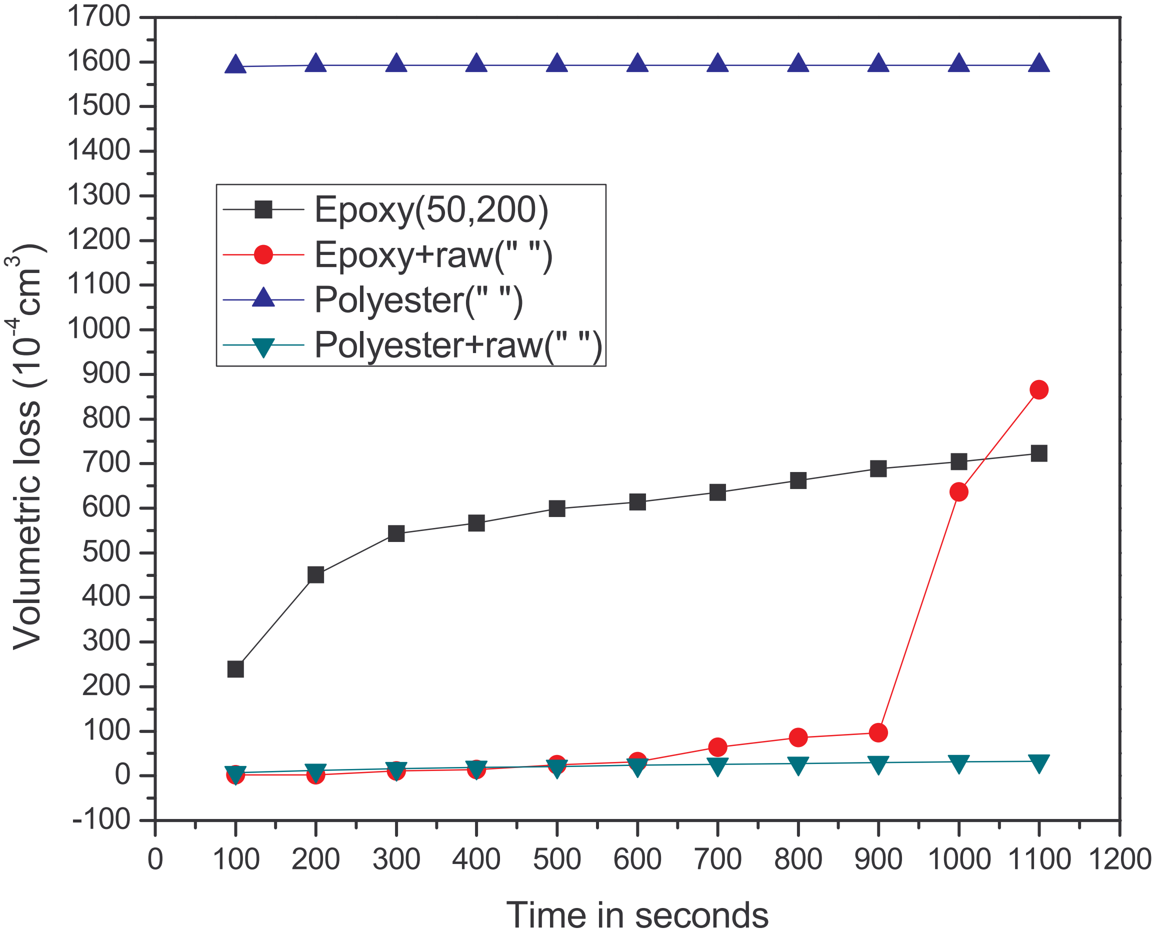

Epoxy(50,200)
Epoxy+raw(" ")
Polyester(" ")
Polyester+raw(" ")
Volumetric loss (10^-4cm^3)
Time in seconds
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200

Figure:-7

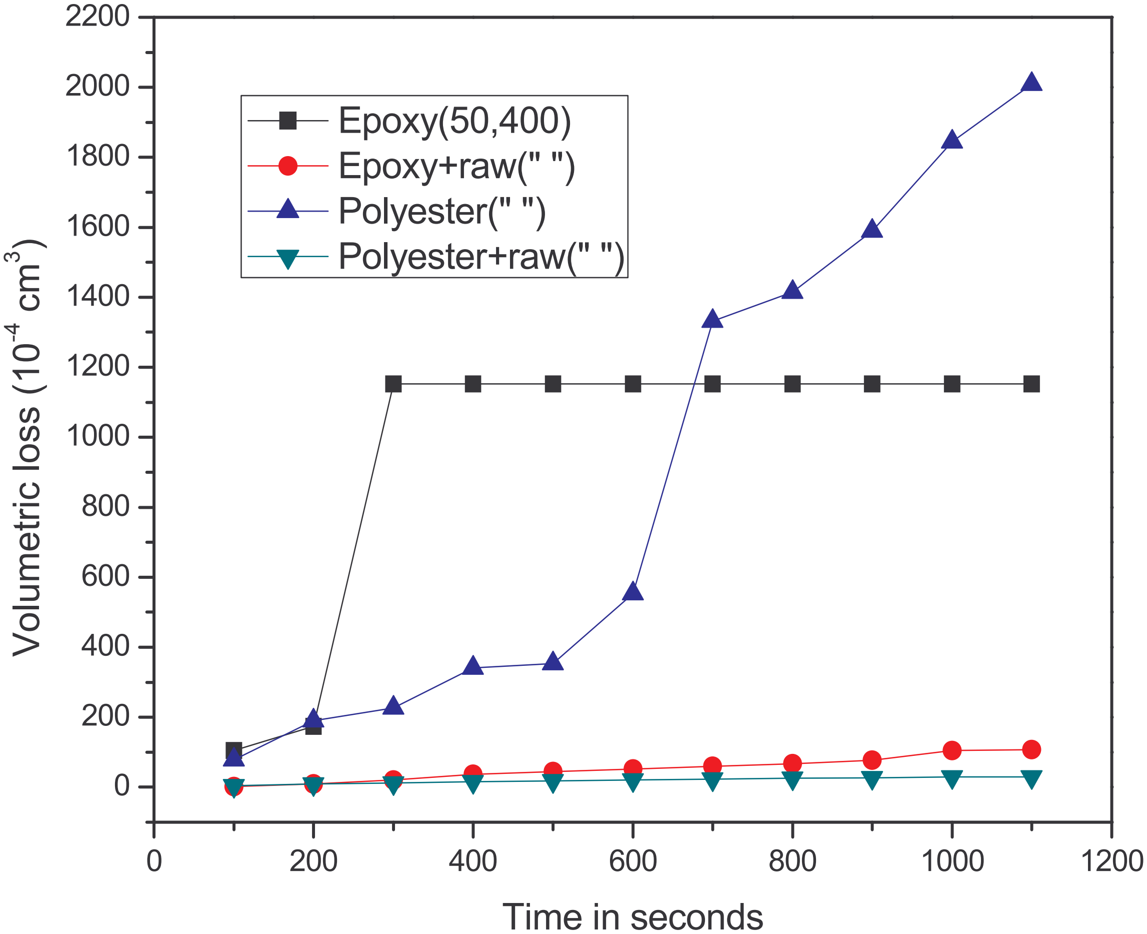


Figure:-8

Fig. 5,6,7,8 show that slide wear resistant of feather reinforced epoxy composite and polyester composite is more than their corresponding neat epoxy and polyester at higher load and higher rpm.

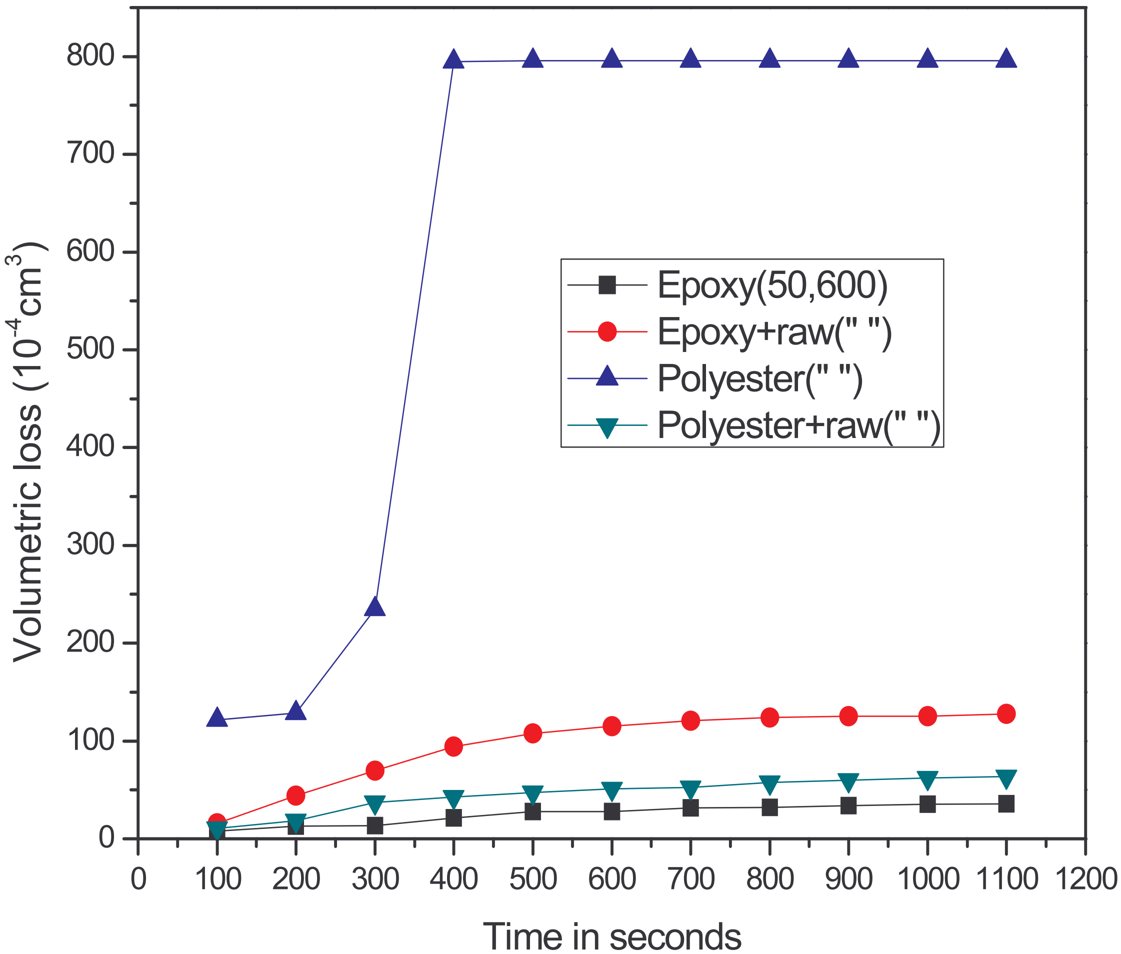


Figure:-9

Here also both feather reinforced epoxy and polyester composite follows the parabolic path and greater slide wear resistant.

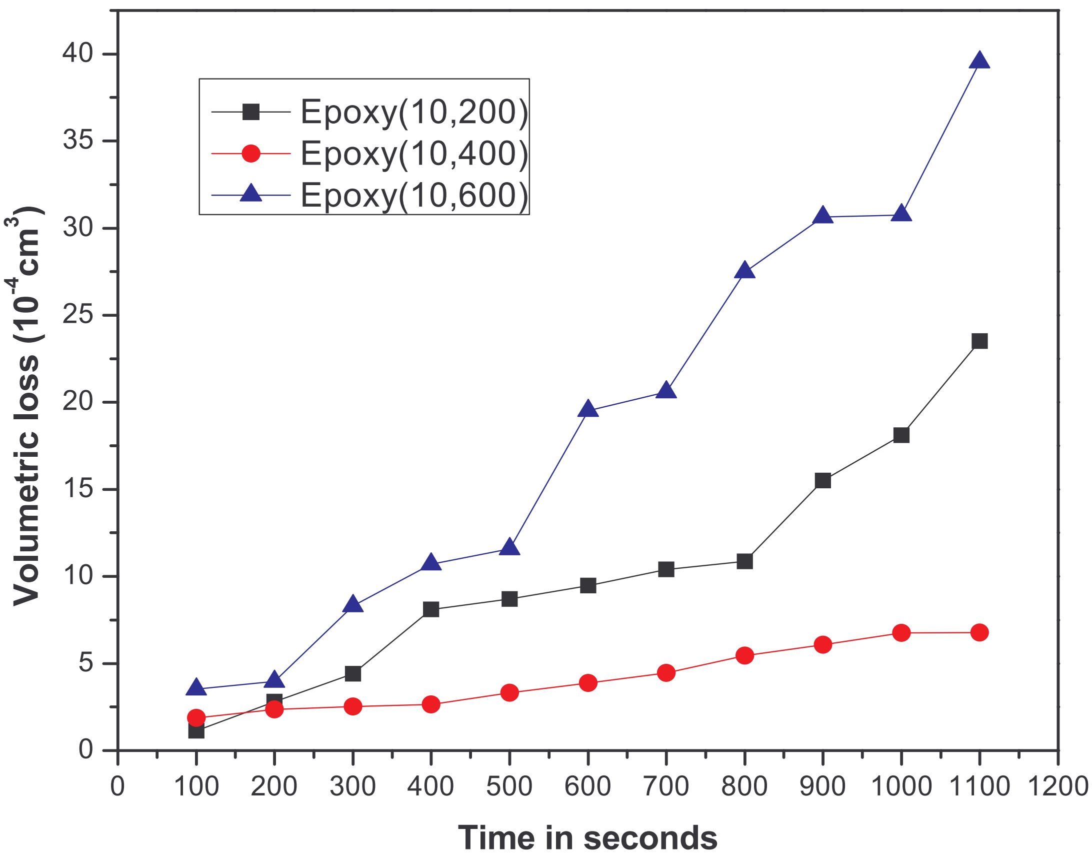

Epoxy(10,200)
Epoxy(10,400)
Epoxy(10,600)
Volumetric loss ($10^{-4}cm^3$)
0
5
10
15
20
25
30
35
40
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Time in seconds

Figure :- 10

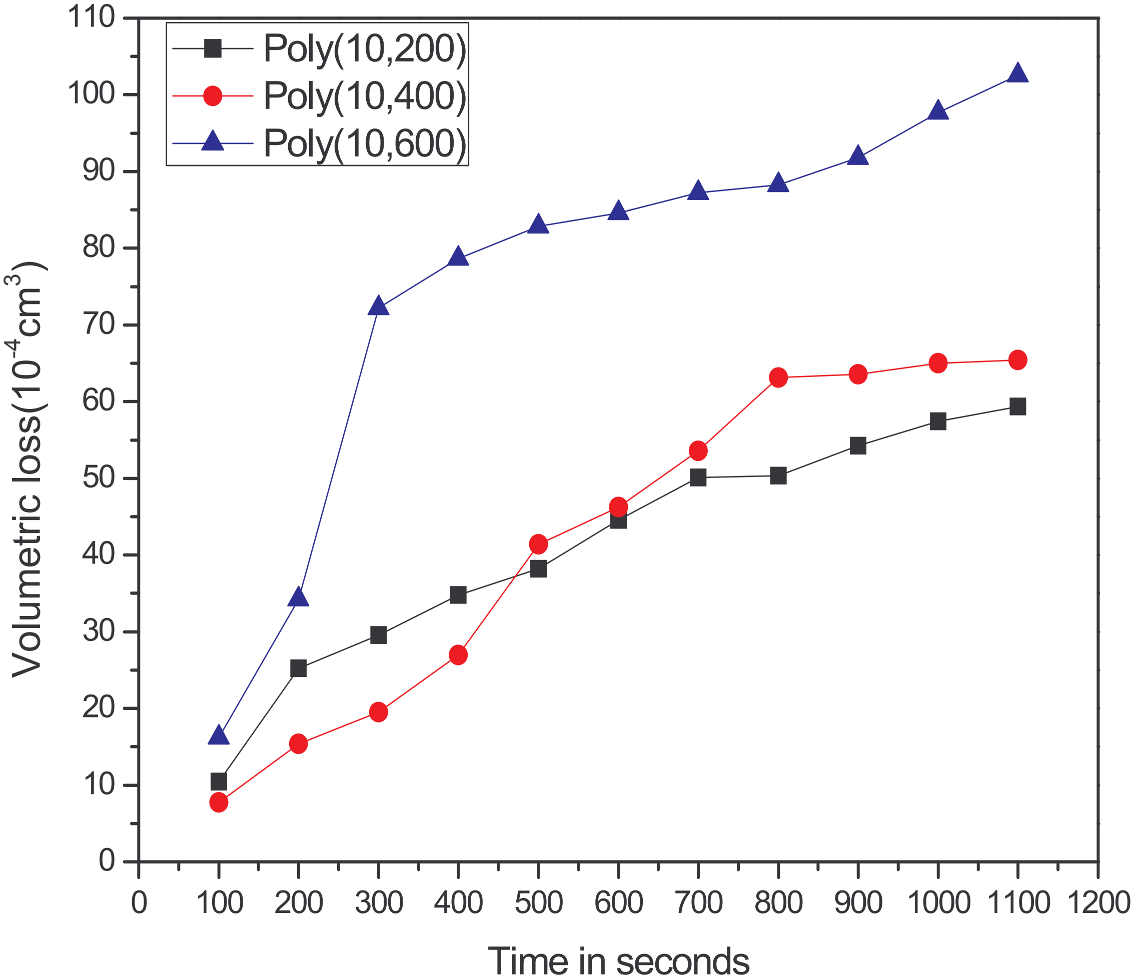
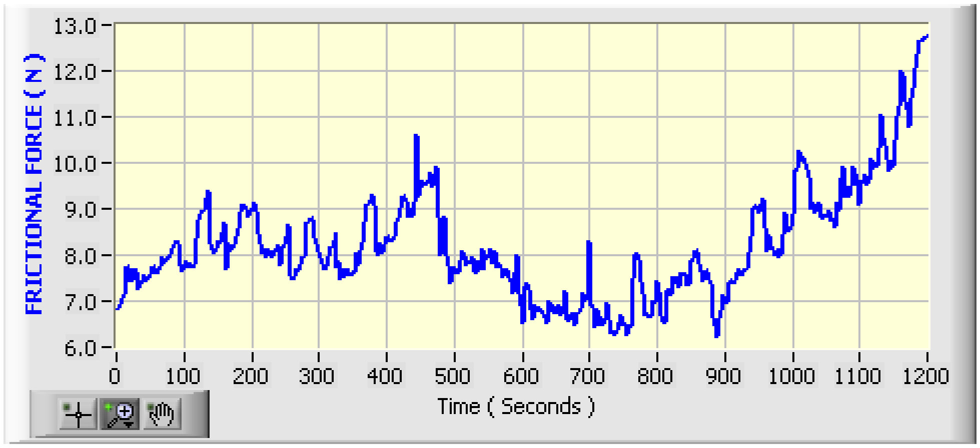


Figure :- 11

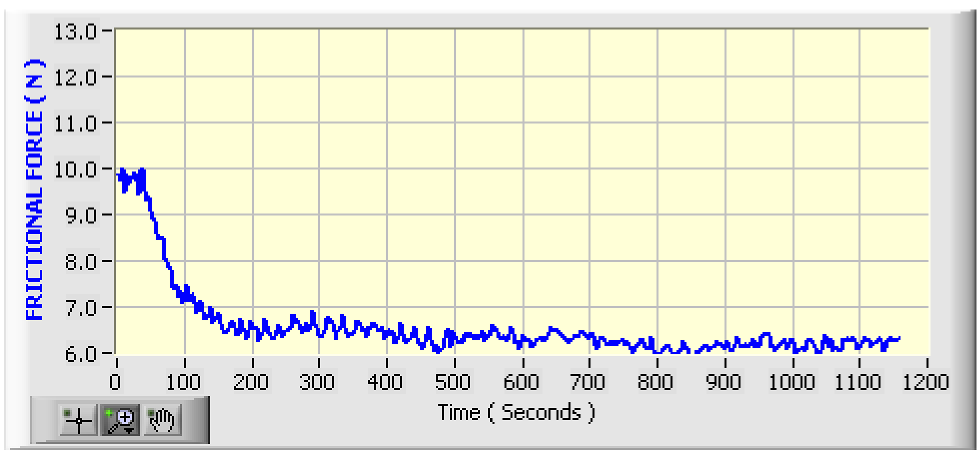
From the fig. 10 and Fig. 11,we studied that neat epoxy has more slide wear resistant than neat polyester under same load and same rpm.

Variation of friction with time are represented as follows:



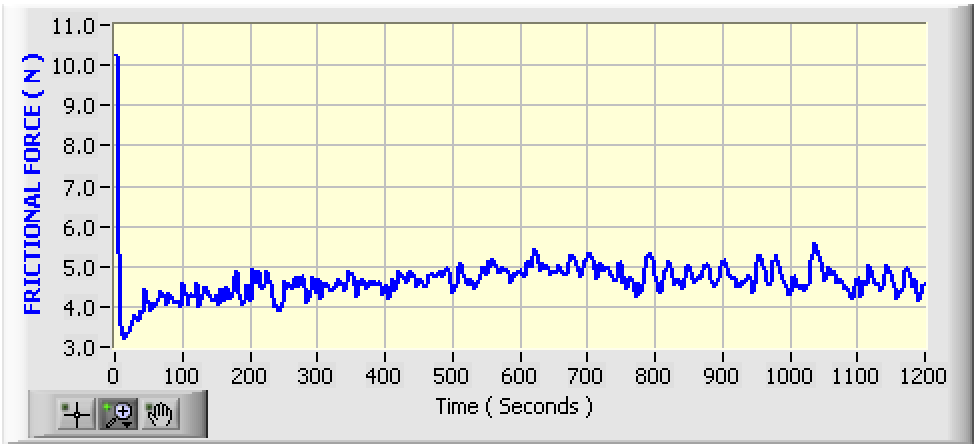
Epoxy (10+200)

Here the frictional force first increases, than decreases and again increases continuously.



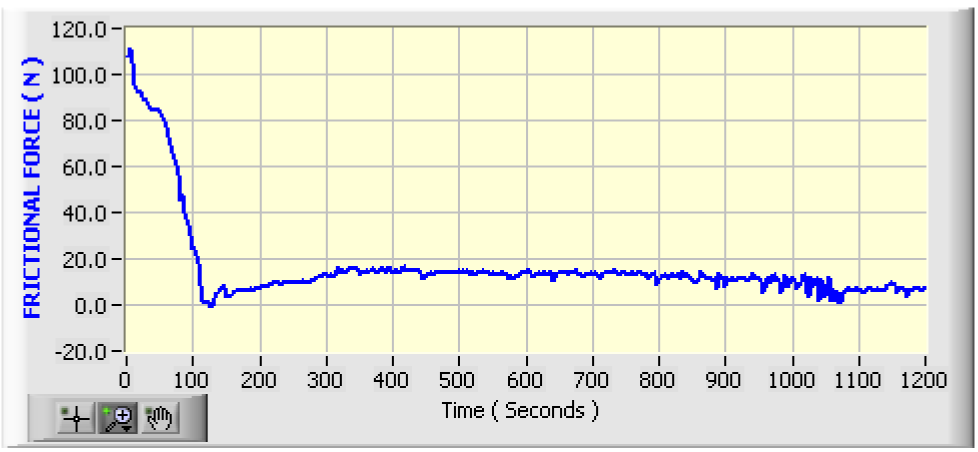
Epoxy (10,400)

Here frictional force is maximum initially and after that decreases continuously.



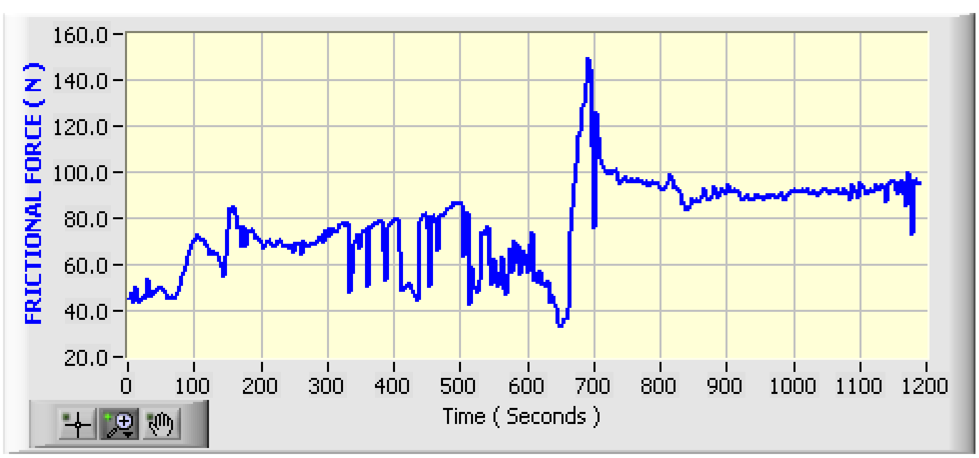
Epoxy (10,600)

Here frictional force decreases sharply in initial 20 sec. and after that it increases slightly and attains a almost constant value.



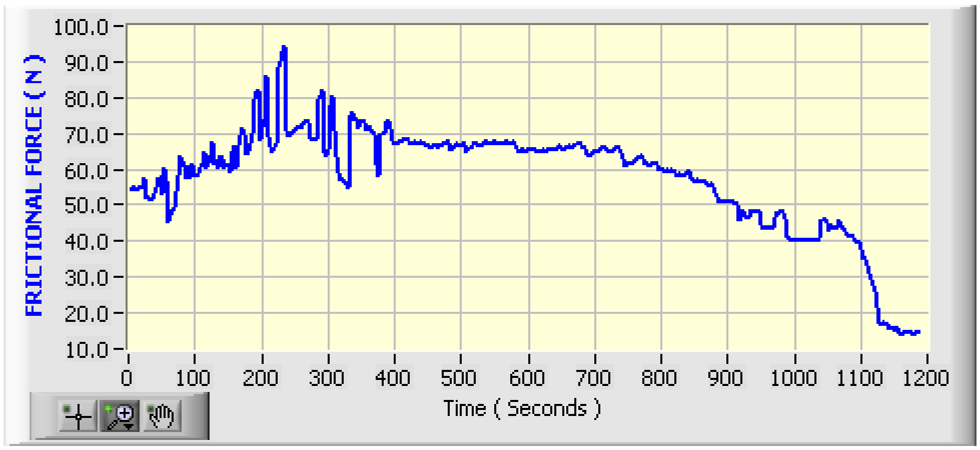
Epoxy(20,200)

Here frictional force decreases parabolically from its original value upto 100 sec, then it increases slightly and attains a constant value.



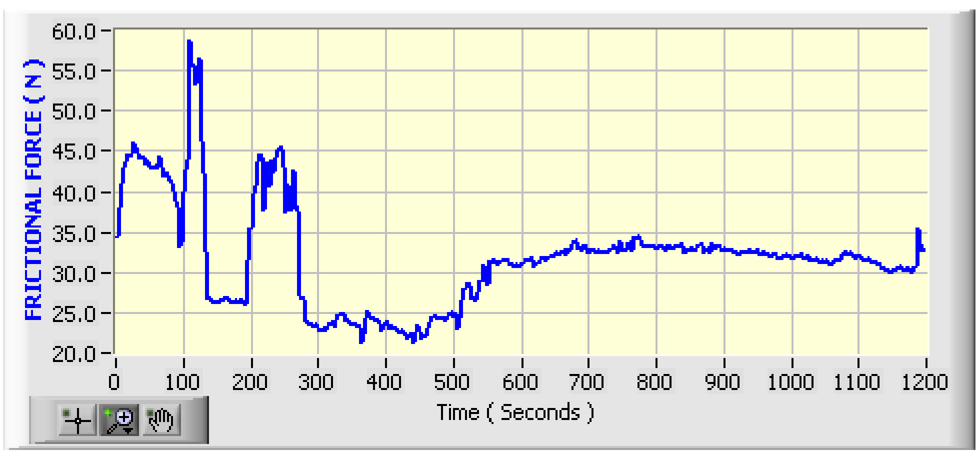
Epoxy (20,400)

Here frictional force attains max. value at 698 sec and after that it decreases sharply and attains almost constant value.



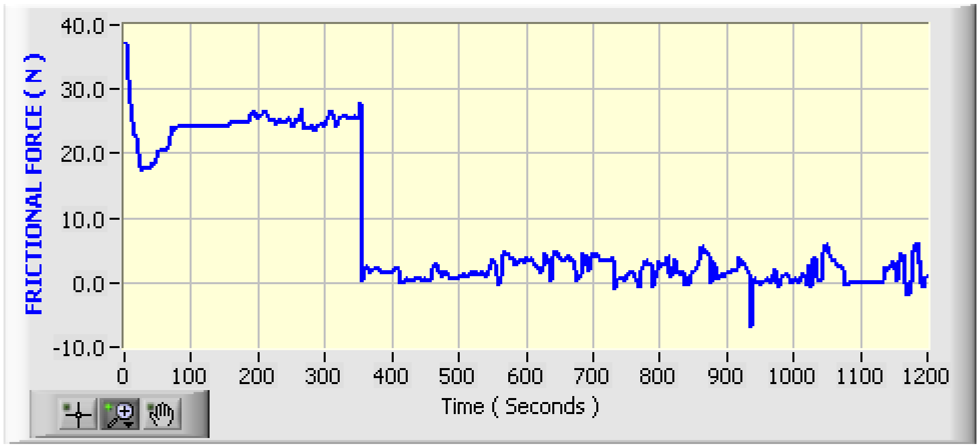
Epoxy (20,600)

Here frictional force decreases continuously in a parabolic way.



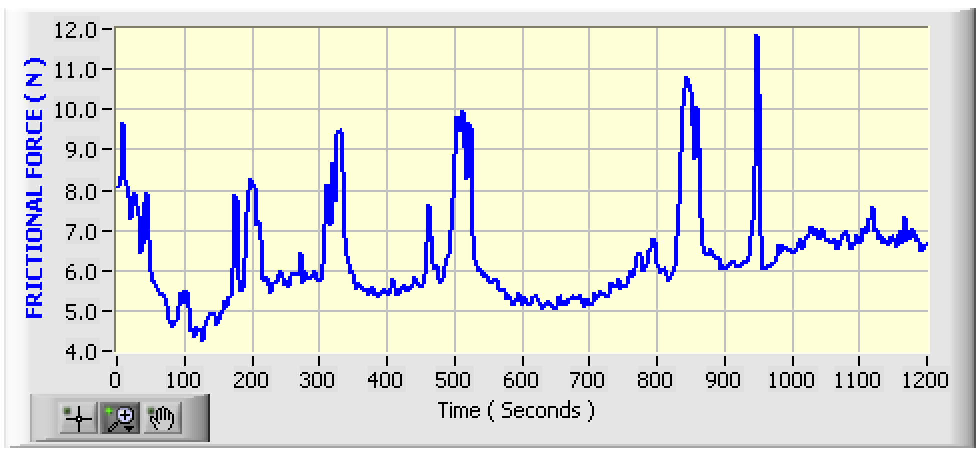
Epoxy (50,200)

Here frictional force attains max. value at 100 sec. and after that it varies irregularly and it attains almost constant value after 700 sec.



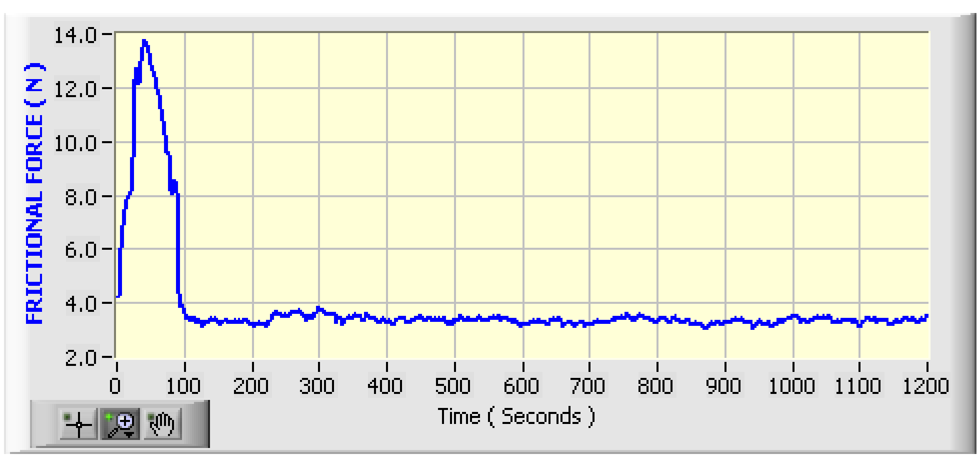
Epoxy (50,400)

Here frictional force decreases with time and attains its min. value in between 900 to 1000 sec.



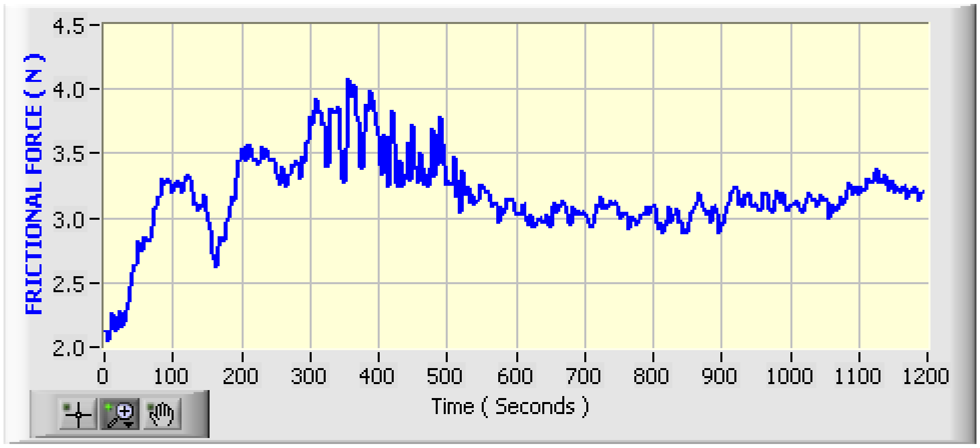
Epoxy(50,600)

Here frictional force attains its minimum value at 120 sec and max. value at 950 sec.



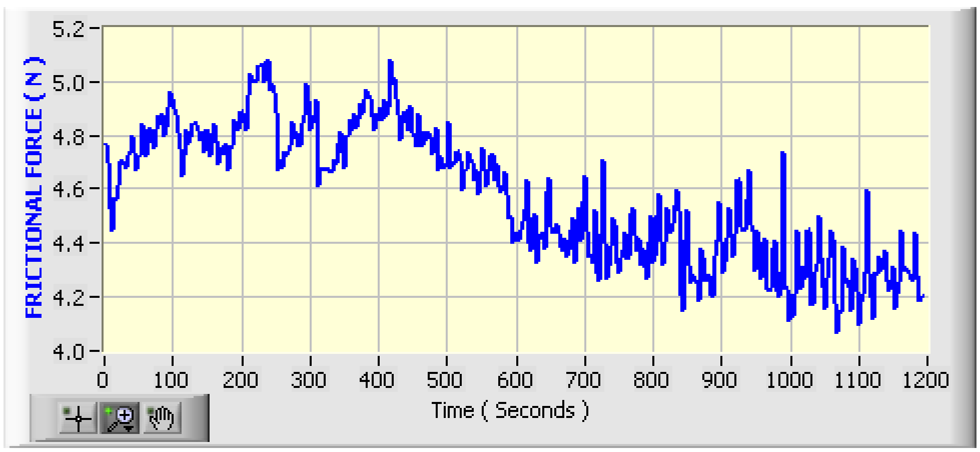
Epoxy + raw (10,200)

Here frictional force attains a constant value after 100 sec.



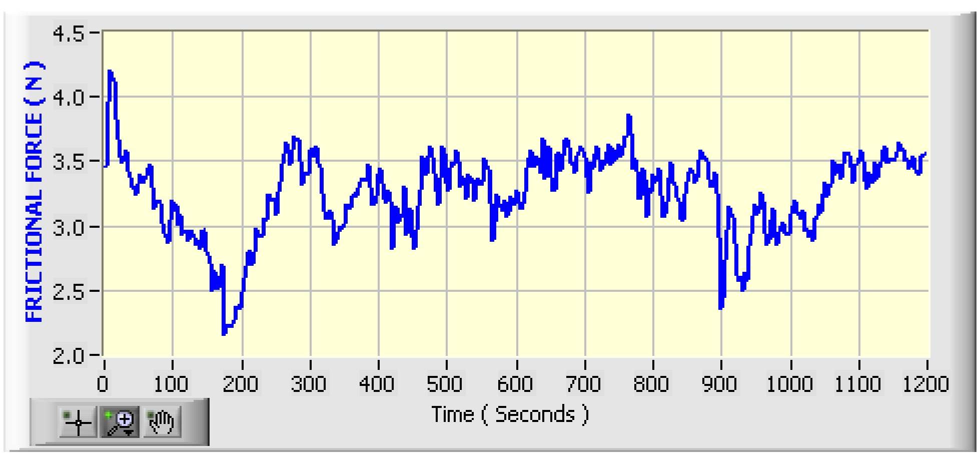
Epoxy + raw(10,400)

Here frictional force varies irregularly with time and maintains max. value near 360 sec.

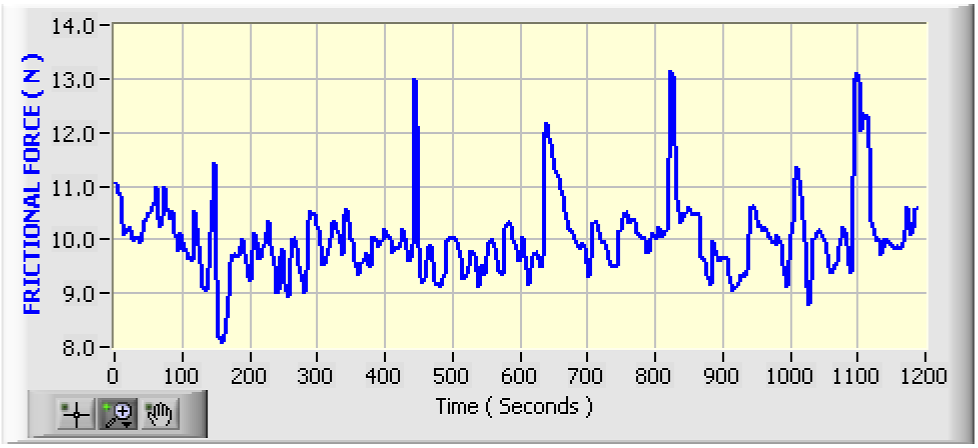


Epoxy + raw (10,600)

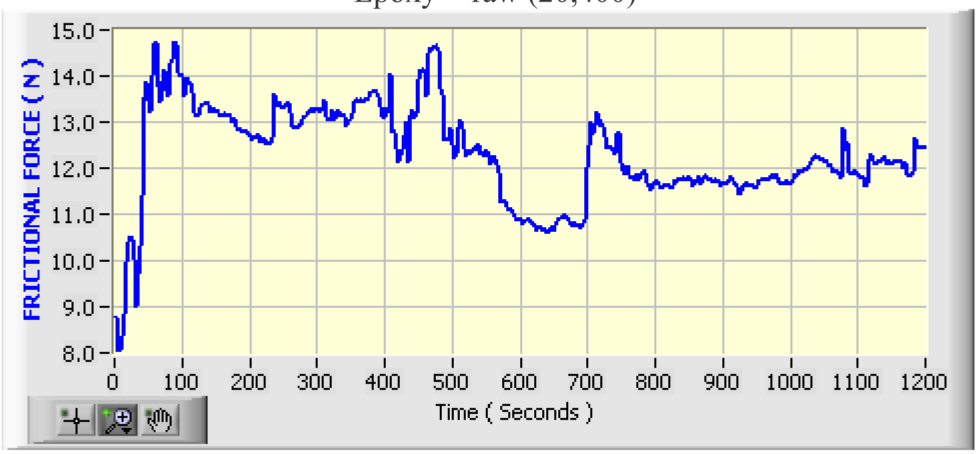
Here also frictional force varies irregularly and attains its max. value at 420 sec.



Epoxy + raw (20,200)

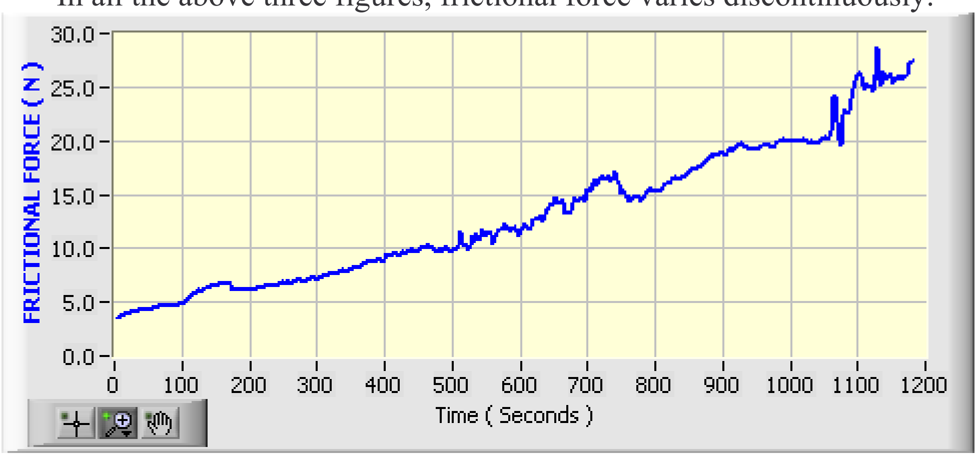


Epoxy + raw (20,400)



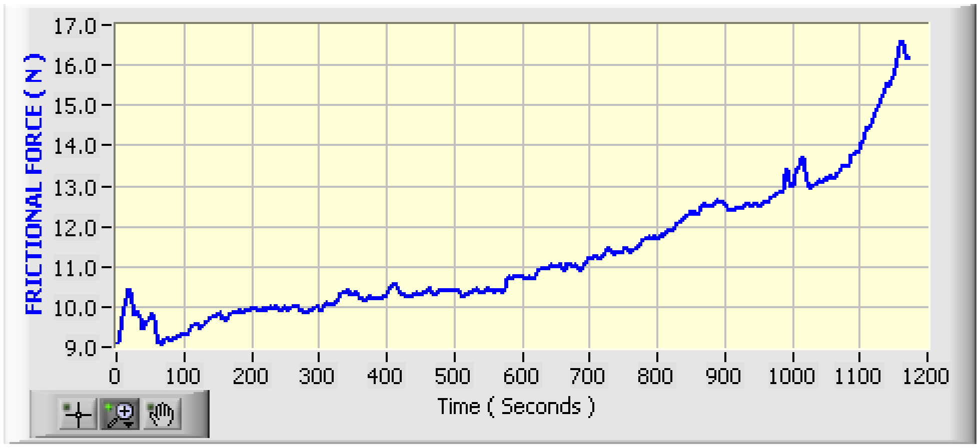
Epoxy + raw (20,600)

In all the above three figures, frictional force varies discontinuously.



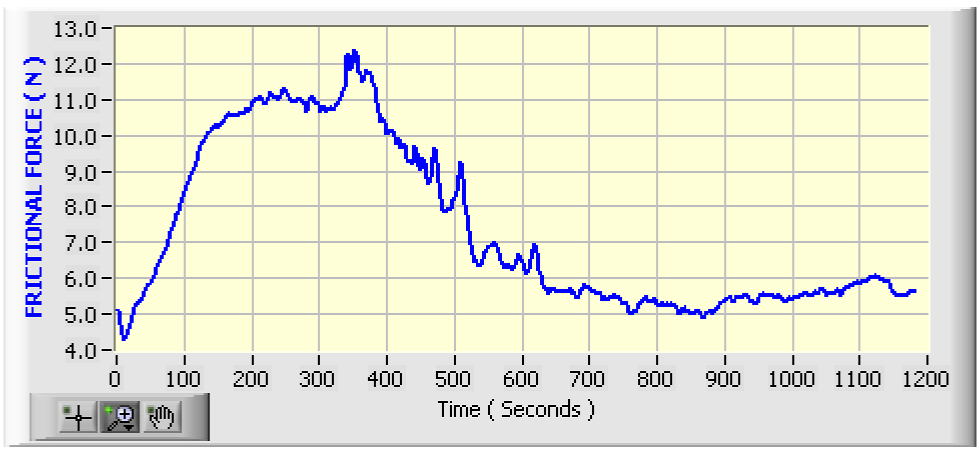
Epoxy + raw (50,200)

Here frictional force increases continuously almost linearly.



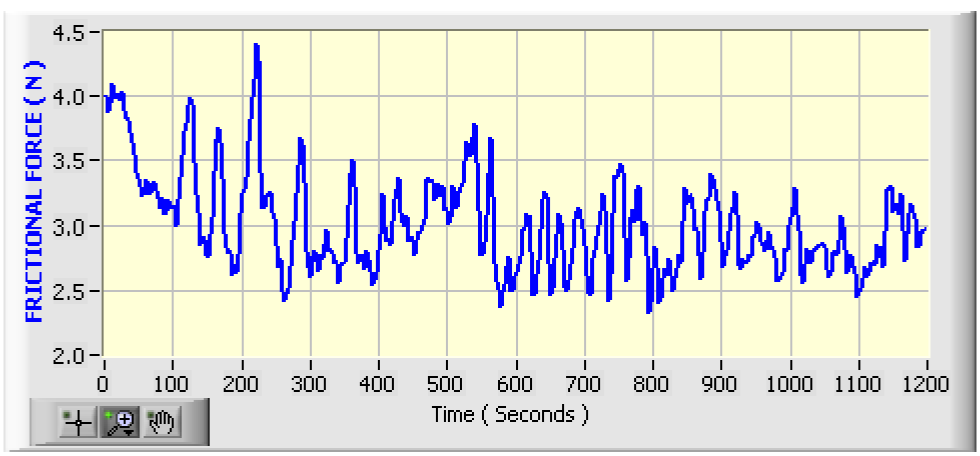
Epoxy + raw (50,400)

Here also frictional force increases continuously and follows a hyperbolic path.

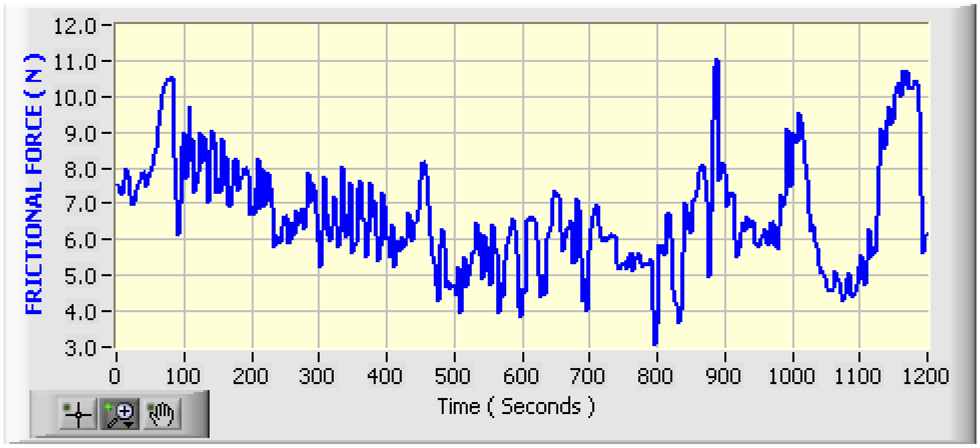


Epoxy + raw (50,600)

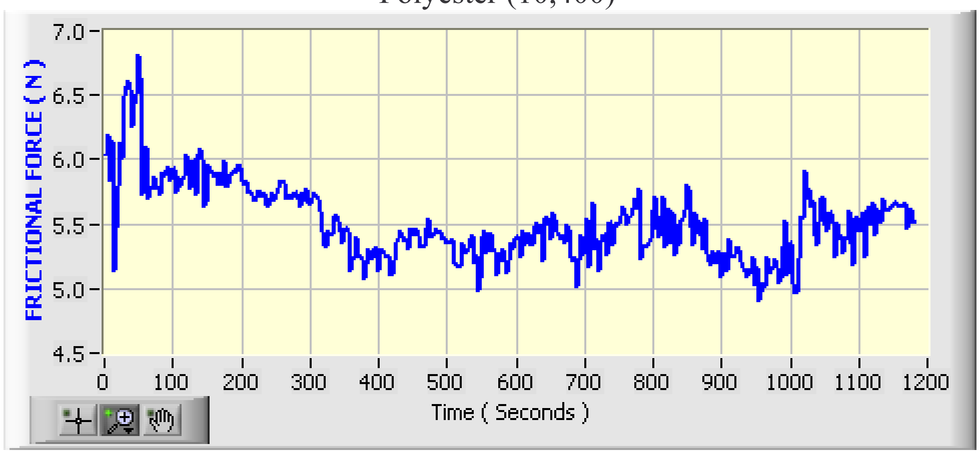
Here frictional force increases initially and attains its ax. Value at 350 sec. and after that it decreases.



Polyester (10,200)

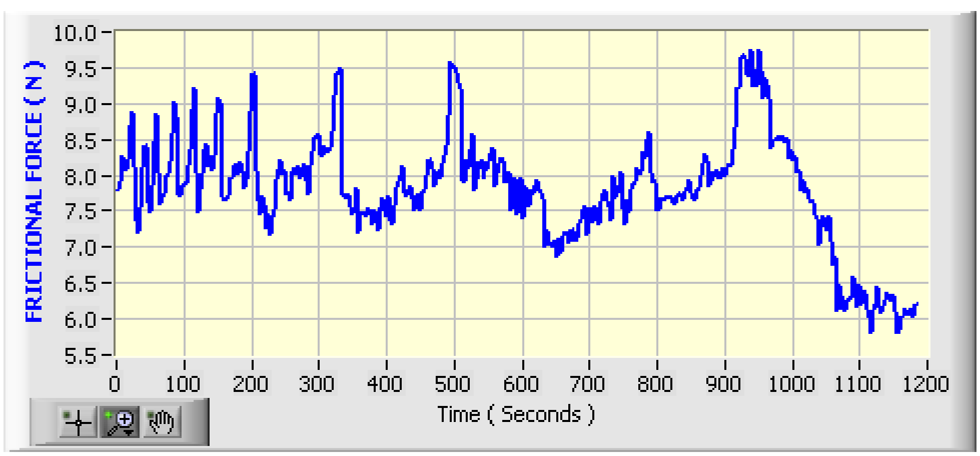


Polyester (10,400)



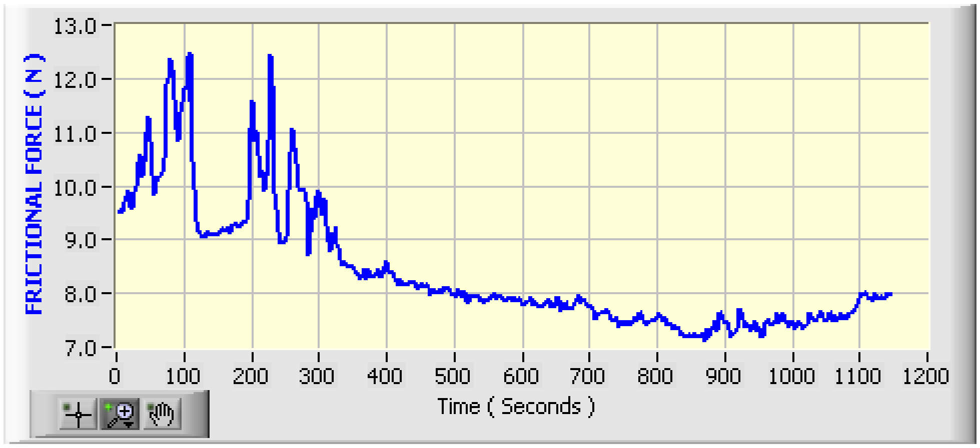
Polyester (10,600)

In the above three figures frictional force varies randomly.



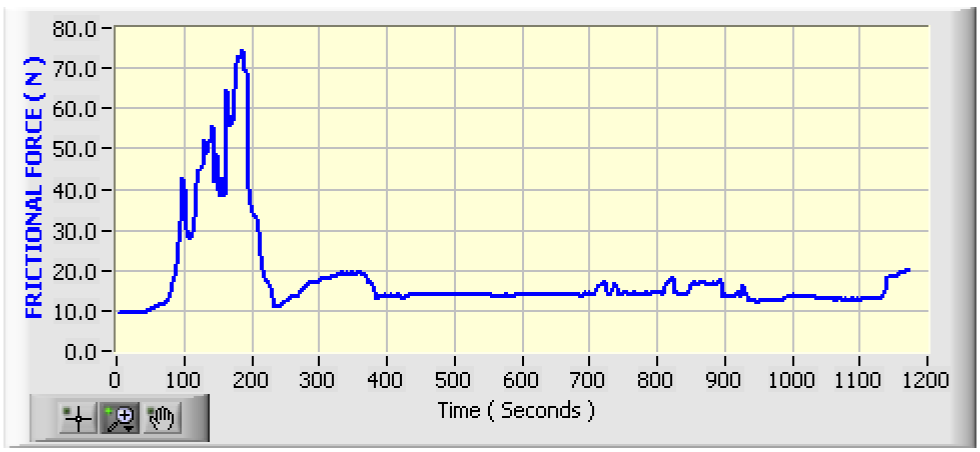
Polyester (20,200)

Here also frictional force varies randomly and attains its max. value at 940 sec.



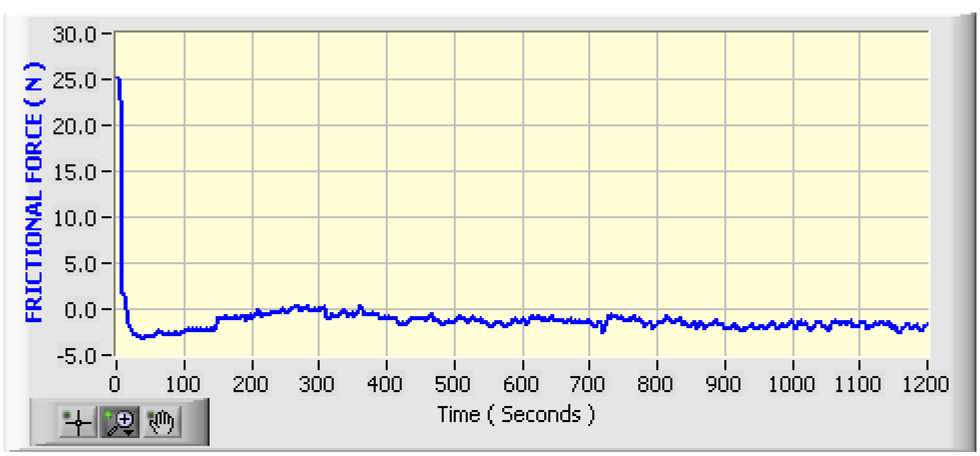
Polyester (20,400)

Here frictional force decreases continuously after 300 sec.



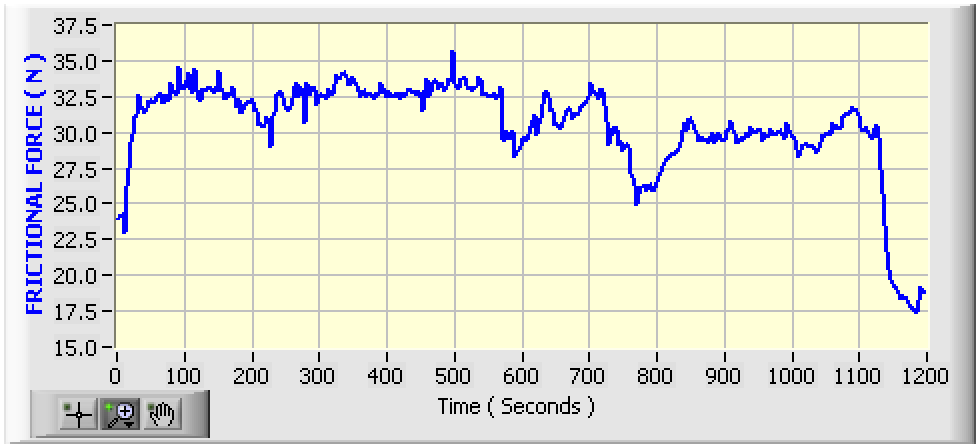
Polyester (20,600)

Here frictioal force attains almost constant value after 400 sec.

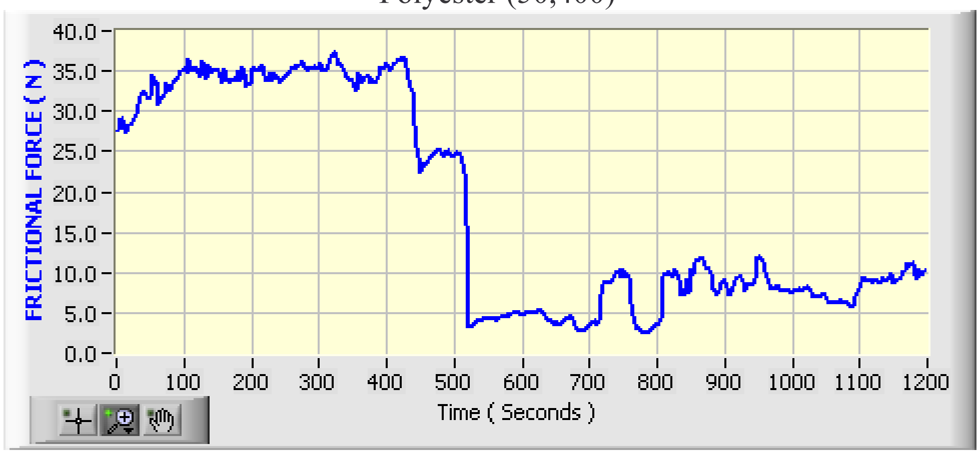


Polyester (50,200)

Here frictional force decreases suddenly and after that 200 sec. it remains constant

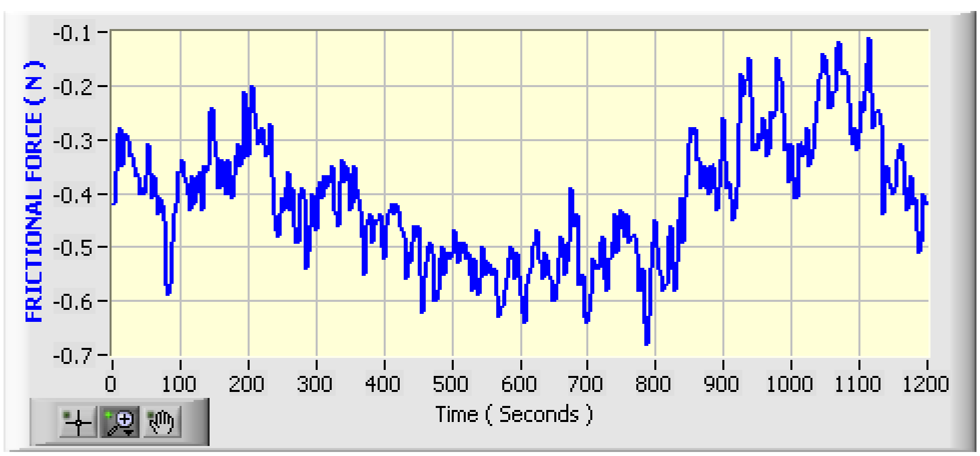


Polyester (50,400)



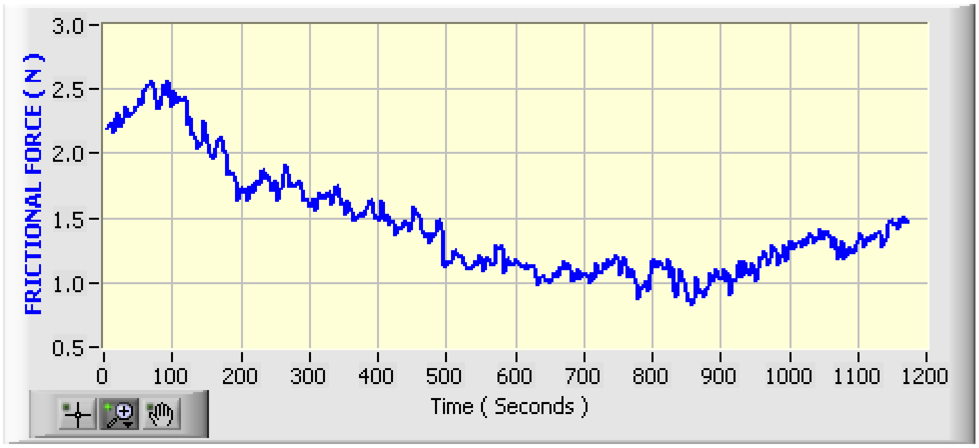
Polyester (50,600)

In Polyester (50,400) and polyester (50,600), frictional force varies randomly.



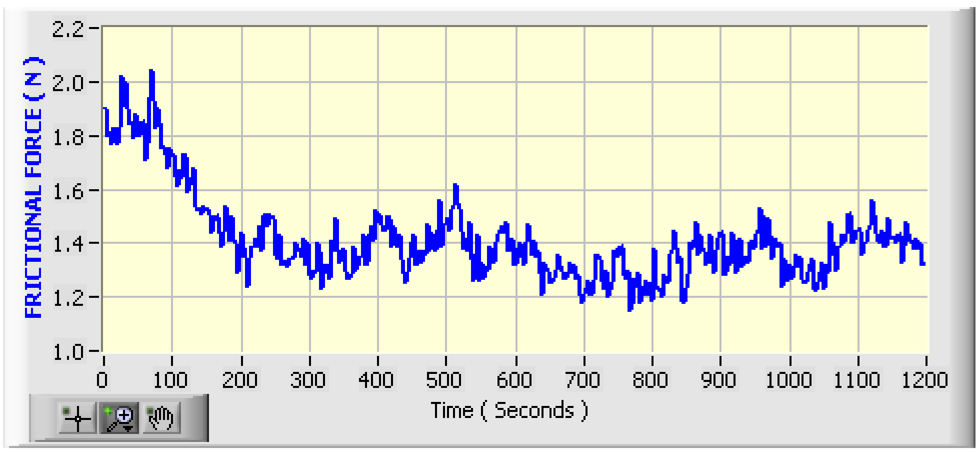
Polyester + raw (10,200)

Here also frictional force varies randomly and attains min. value at 790 sec.



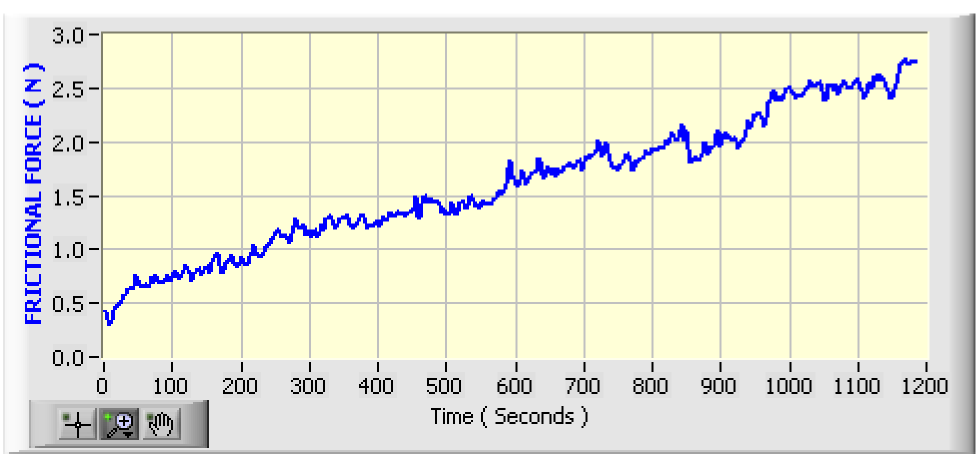
Polyester + raw (10,400)

Here frictional force initially increases. then decreases and again increases towards its end.



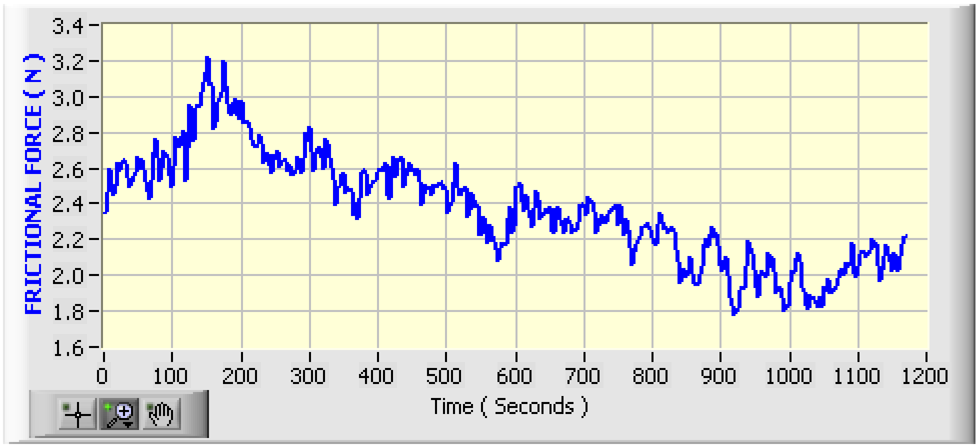
Polyester + raw (10,600)

Here frictional force decreases upto 200 sec., then its value varies around some constant value of frictional force.



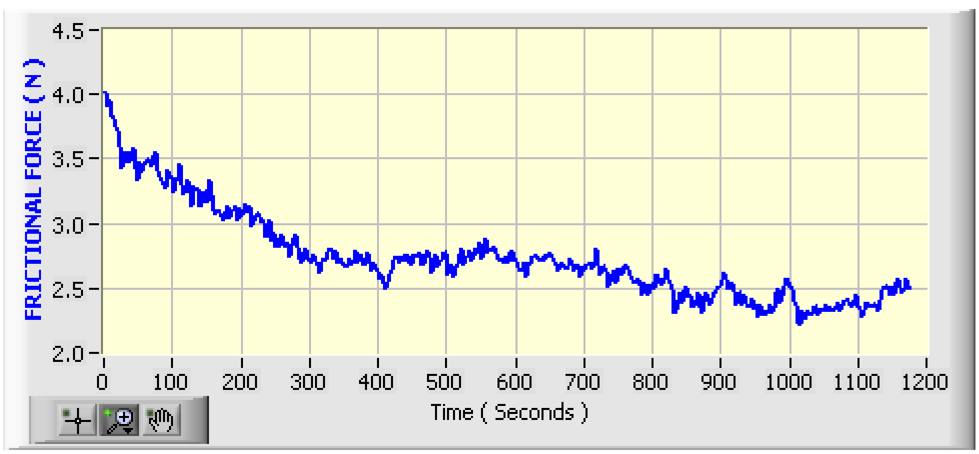
Polyester + raw (20,200)

Here frictional force increases continuously almost in a linear way.



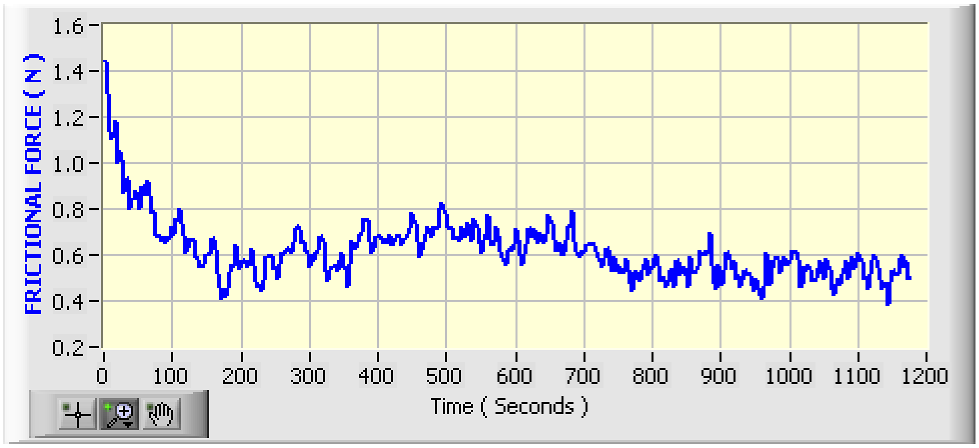
Polyester +raw (20,400)

Here frictional force increases upto 150 sec. and attains a max. value , after that it decreases and towards its end it slightly increases.



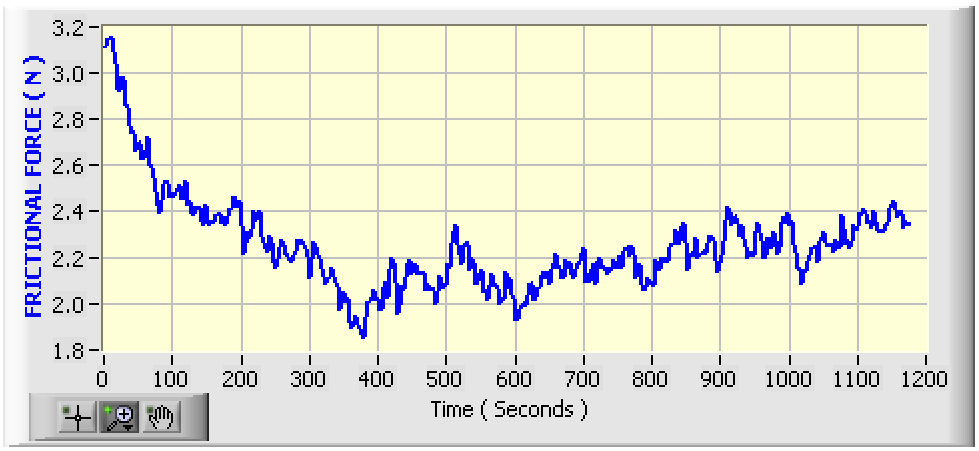
Polyester + raw(20,600)

Here value of frictional force continuously decreases.



Polyester + raw (50,200)

Here also value of frictional force decreases continuously.



Polyester + raw (50,400)

Here frictional force decreases upto 400 sec. then after it increases continuously.

Polyester + raw (50,600)

Here frictional force attains its max. value at 120 sec. and after that it decreases and varied almost constantly with time

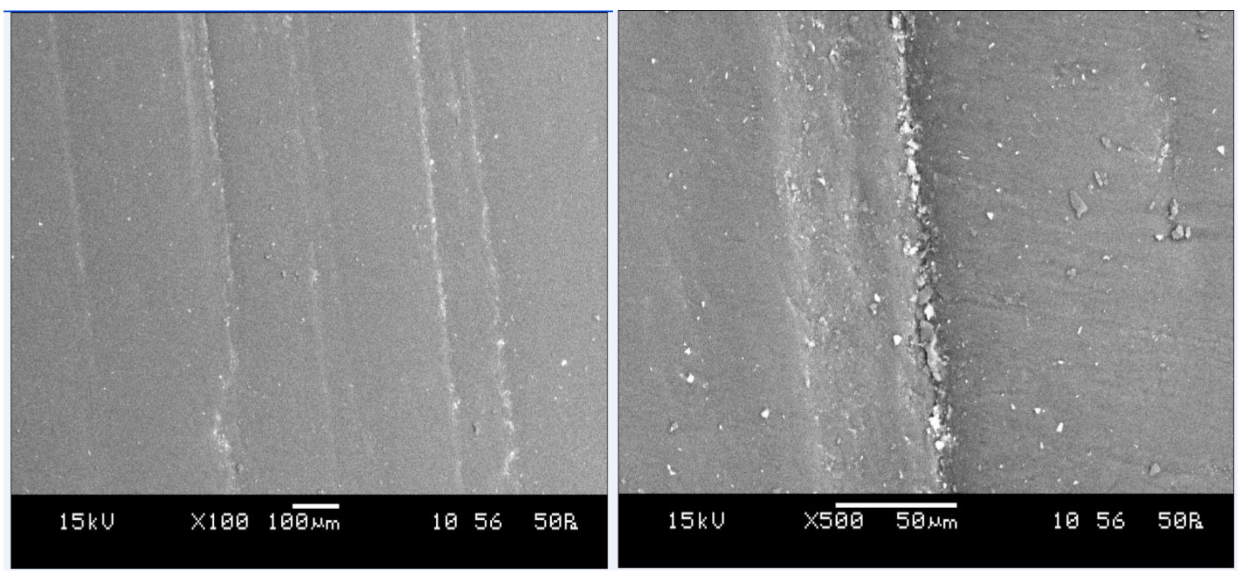
Sample name	Volumetric loss($10^{-10}m^3$)	Distance travelled in m.	Load applied in newton	Specific wear rate(10^{-13} m^3/N-m)
Epoxy(10,200)	23.51	2010.6	9.8	1.193
Epoxy(10,400)	6.77	4021.2	9.8	.171
Epoxy(10,600)	39.54	6031.8	9.8	.668
Epoxy(20,200)	233.61	2010.6	19.6	5.92
Epoxy(20,400)	493.67	4021.2	19.6	6.263
Epoxy(20,600)	173.21	6031.8	19.6	1.465
Epoxy(50,200)	722.63	2010.6	49	7.33
Epoxy(50,400)	1151.88	4021.2	49	5.84
Epoxy(50,600)	35.88	6031.8	49	.121
Epoxy+raw(10,200)	30.27	2010.6	9.8	1.536
Epoxy+raw(10,400)	80.24	4021.2	9.8	2.036
Epoxy+raw(10,600)	66.73	6031.8	9.8	1.128
Epoxy+raw(20,200)	101.73	2010.6	19.6	2.58
Epoxy+raw(20,400)	213.21	4021.2	19.6	2.705
Epoxy+raw(20,600)	144.78	6031.8	19.6	1.224
Epoxy+raw(50,200)	865.36	2010.6	49	8.78
Epoxy+raw(50,400)	107.33	4021.2	49	.5447
Epoxy+raw(50,600)	127.88	6031.8	49	.4326

Sample name	Volumetric loss($10^{-10}m^3$)	Distance travelled in m.	Load applied in newton	Specific wear rate(10^{-13} m^3/N-m)
Polyester(10,200)	59.36	2010.6	9.8	3.012
Polyester(10,400)	65.40	4021.2	9.8	1.65
Polyester(10,600)	102.54	6031.8	9.8	1.73
Polyester(20,200)	445.13	2010.6	19.6	11.295
Polyester(20,400)	115.6	4021.2	19.6	1.46
Polyester(20,600)	542.41	6031.8	19.6	4.588
Polyester(50,200)	1592.44	2010.6	49	16.16
Polyester(50,400)	2009.35	4021.2	49	10.19
Polyester(50,600)	795.61	6031.8	49	2.69
Polyester+raw(10,200)	19.02	2010.6	9.8	0.965
Polyester+raw(10,400)	6.13	4021.2	9.8	0.155
Polyester+raw(10,600)	18.58	6031.8	9.8	0.314
Polyester+raw(20,200)	25.83	2010.6	19.6	0.655
Polyester+raw(20,400)	8.52	4021.2	19.6	0.108
Polyester+raw(20,600)	36.41	6031.8	19.6	0.307

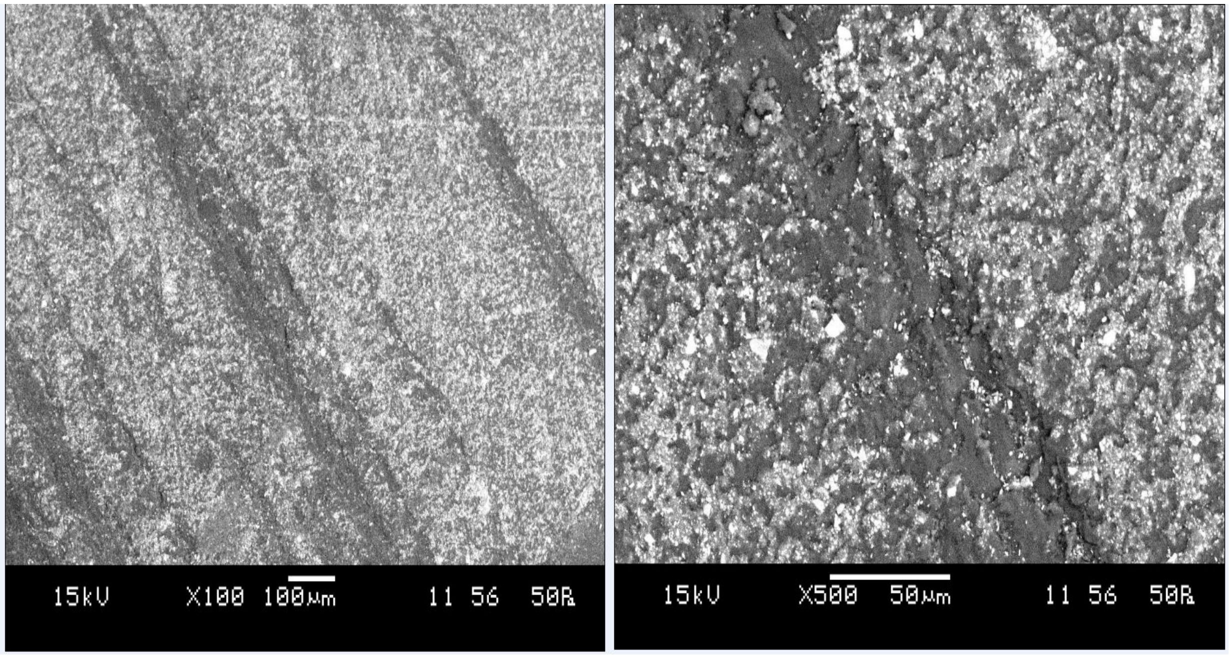
Polyester+raw(50,200)	32.64	2010.6	49	0.331
Polyester+raw(50,400)	29.66	4021.2	49	0.150
Polyester+raw(50,600)	63.41	6031.8	49	0.214

4.2 Scanning **electron microscopy**

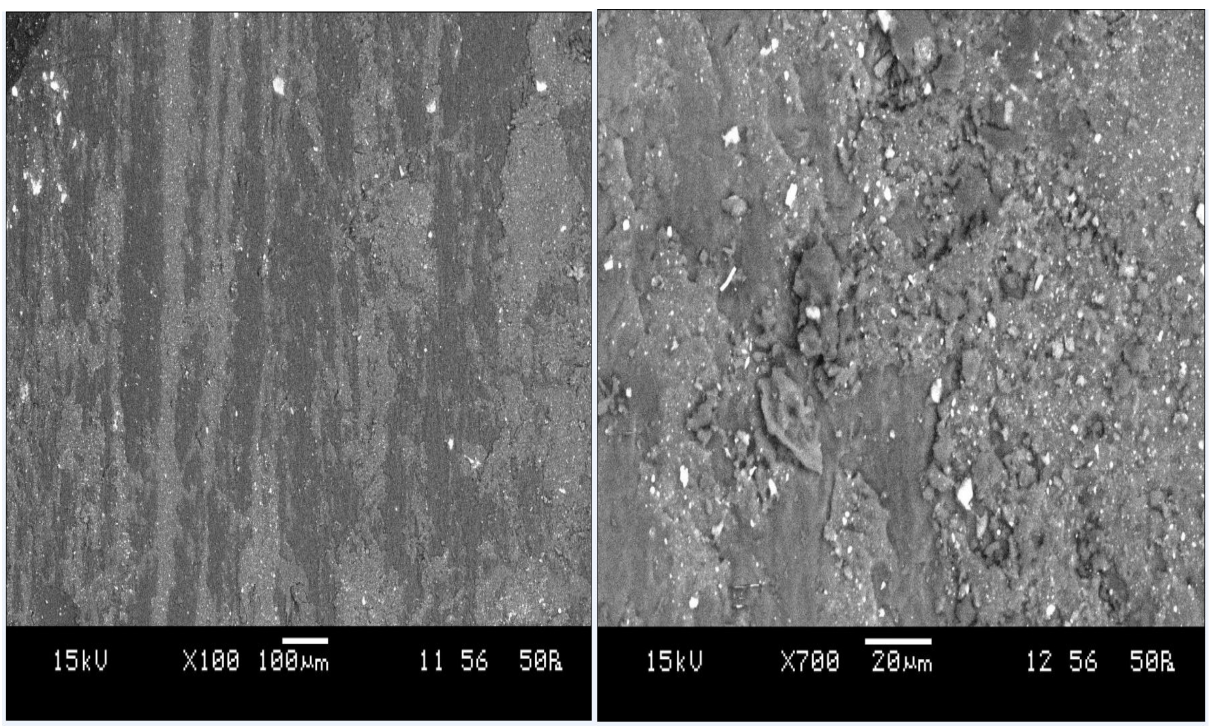
The surfaces of the raw fish scales and the composite specimens are examined directly by scanning electron microscope JEOL JSM-6480LV. The scales are washed, cleaned thoroughly, air-dried and are coated with 100 Å thick platinum in JEOL sputter ion coater and observed SEM at 20 kV. Similarly the composite samples are mounted on stubs with silver paste. To enhance the conductivity of the samples, a thin film of platinum is vacuum-evaporated onto them before the photomicrographs are taken.



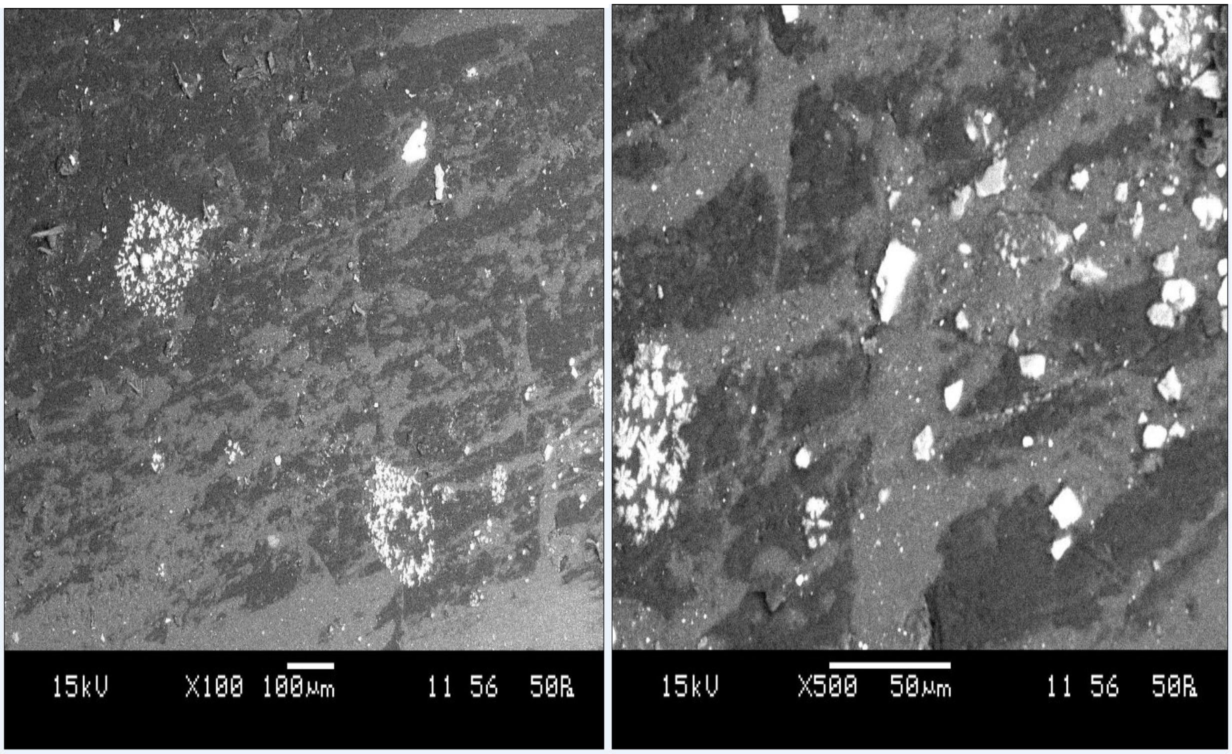
(A) Epoxy-10N, 200 rpm 1-2



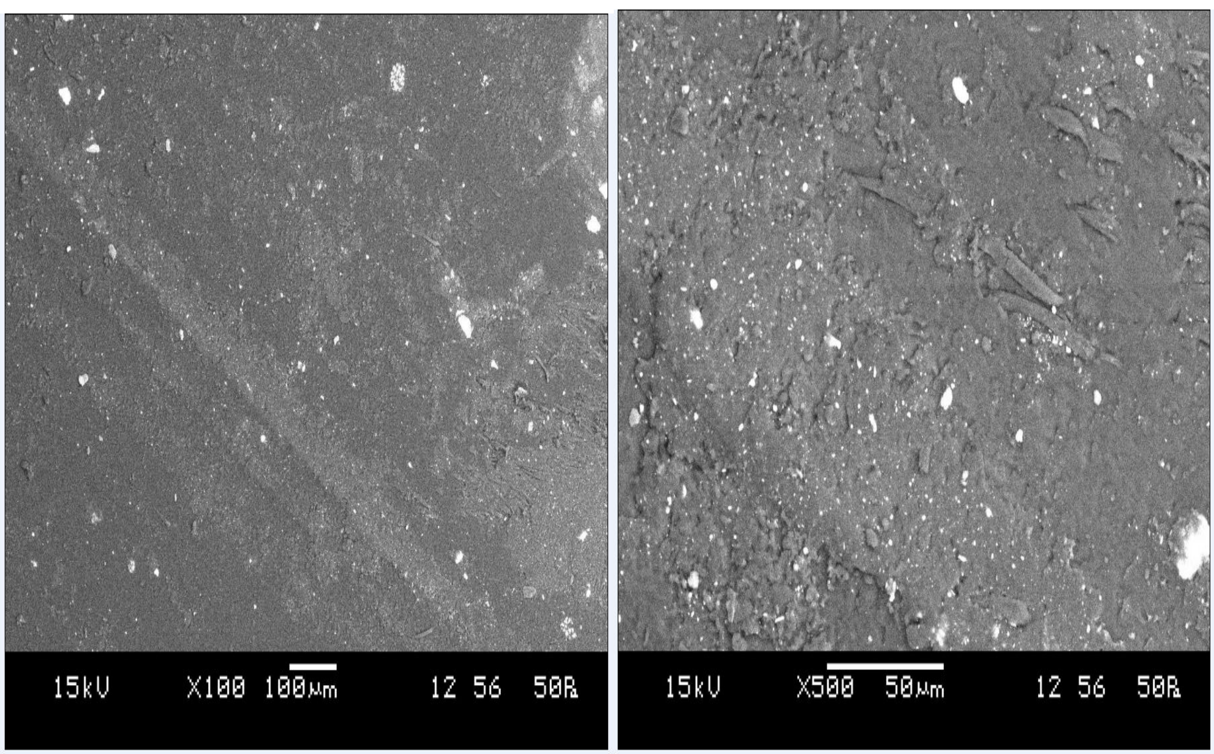
(B)Epoxy-50N, 600 rpm 2-2



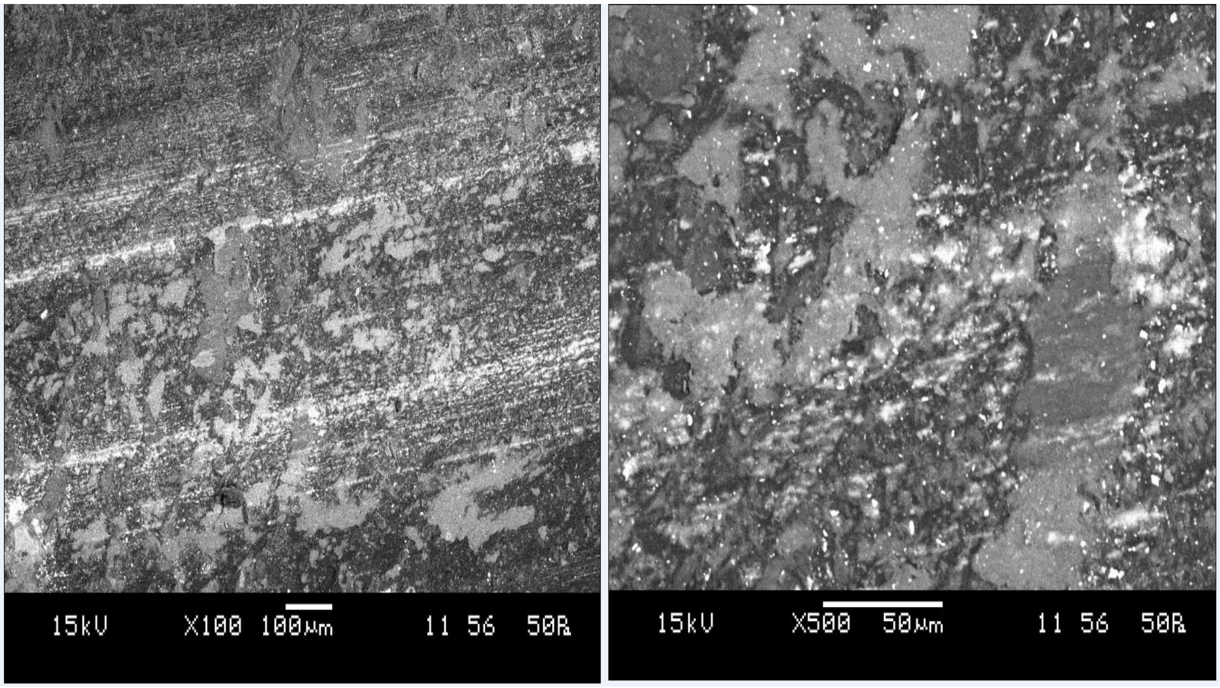
(C)Epoxy+raw-10N, 200 rpm 3-2



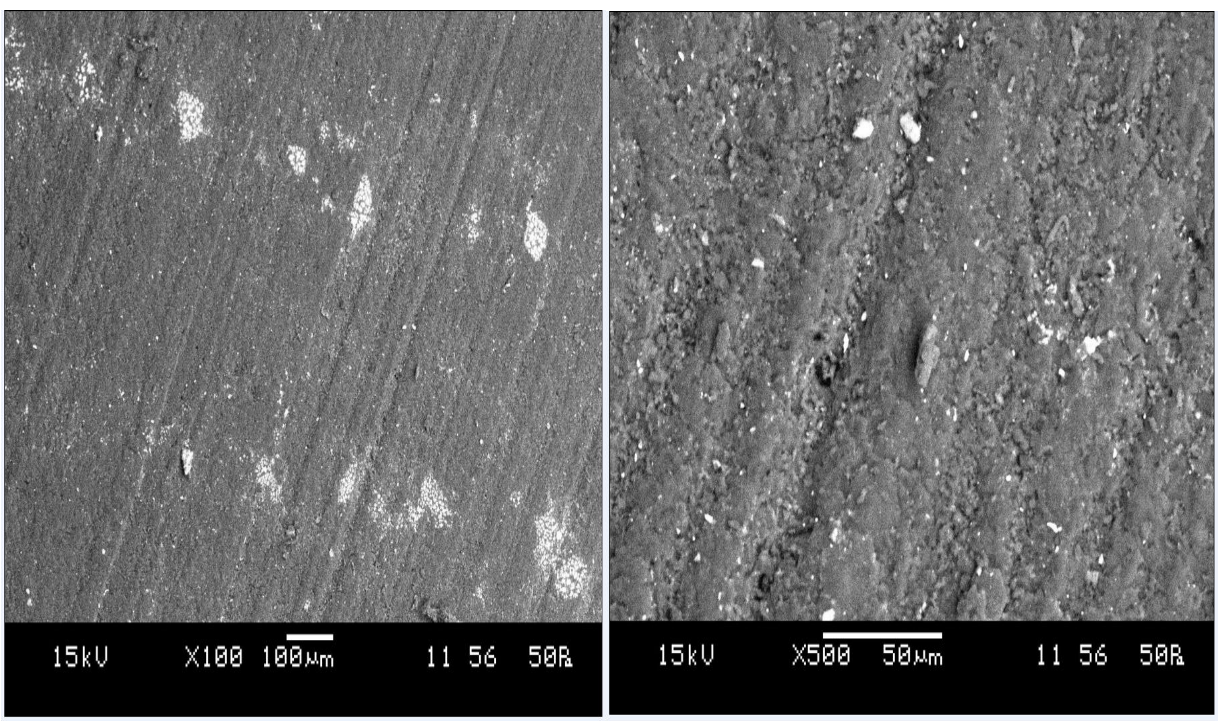
(D)Epoxy+raw-10N, 600 rpm 5-2



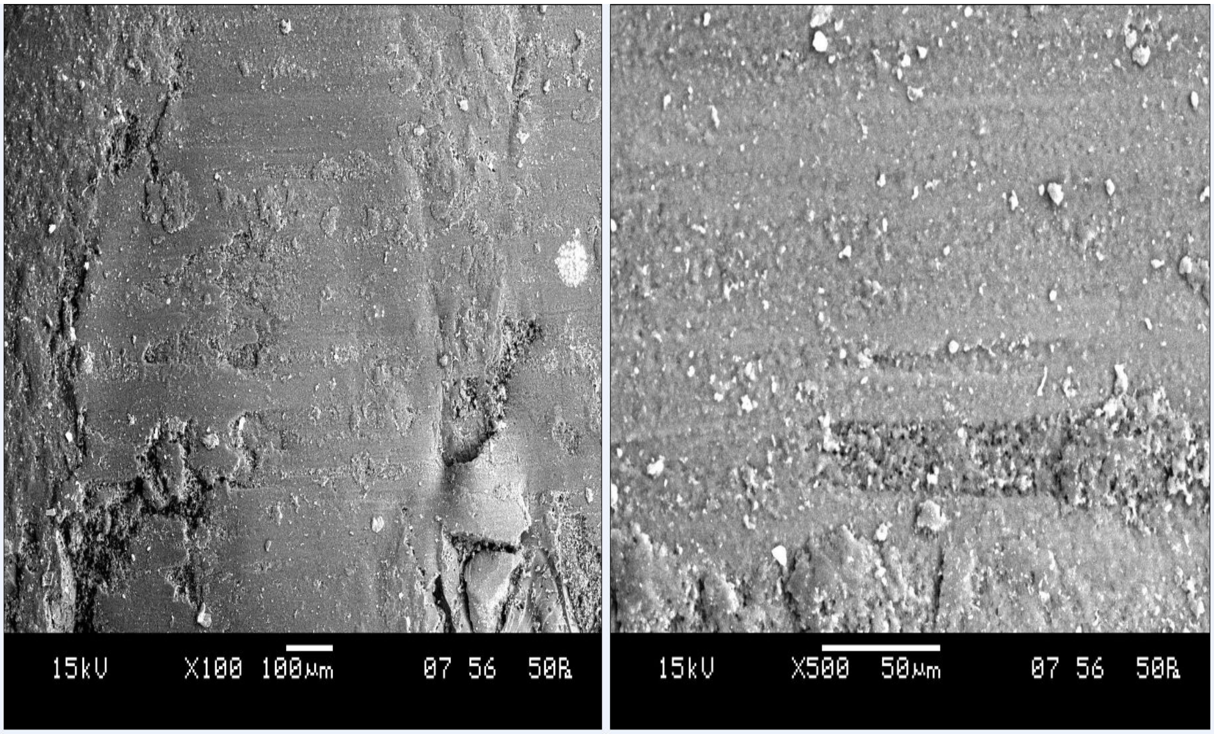
(E)Epoxy+raw-50N, 200 rpm 7-2



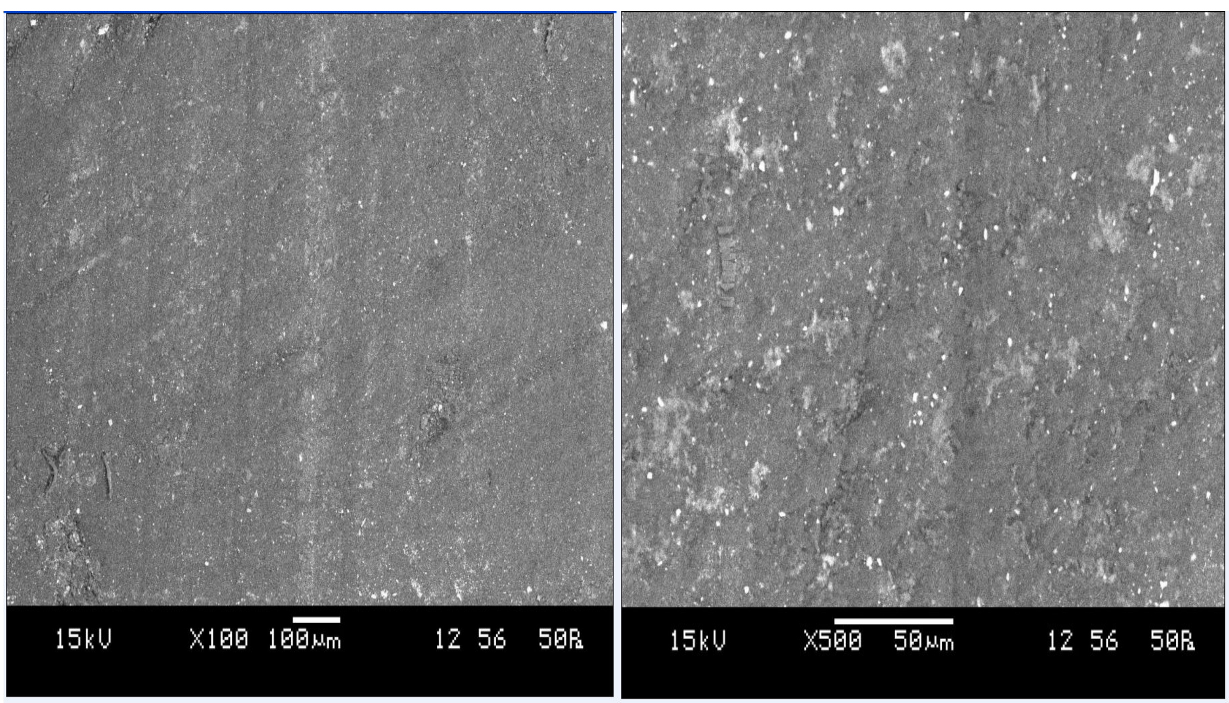
(F)Epoxy+raw-50N, 600 rpm 6-2



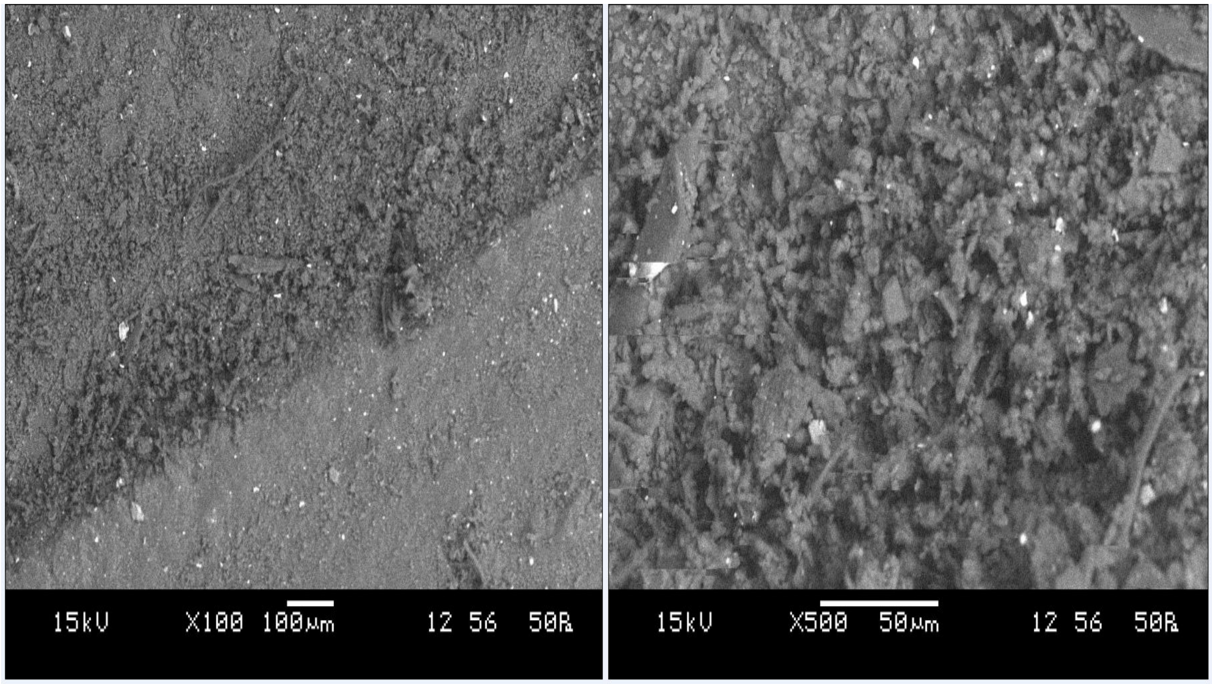
(G)Polyster-10N, 200 rpm 8-2



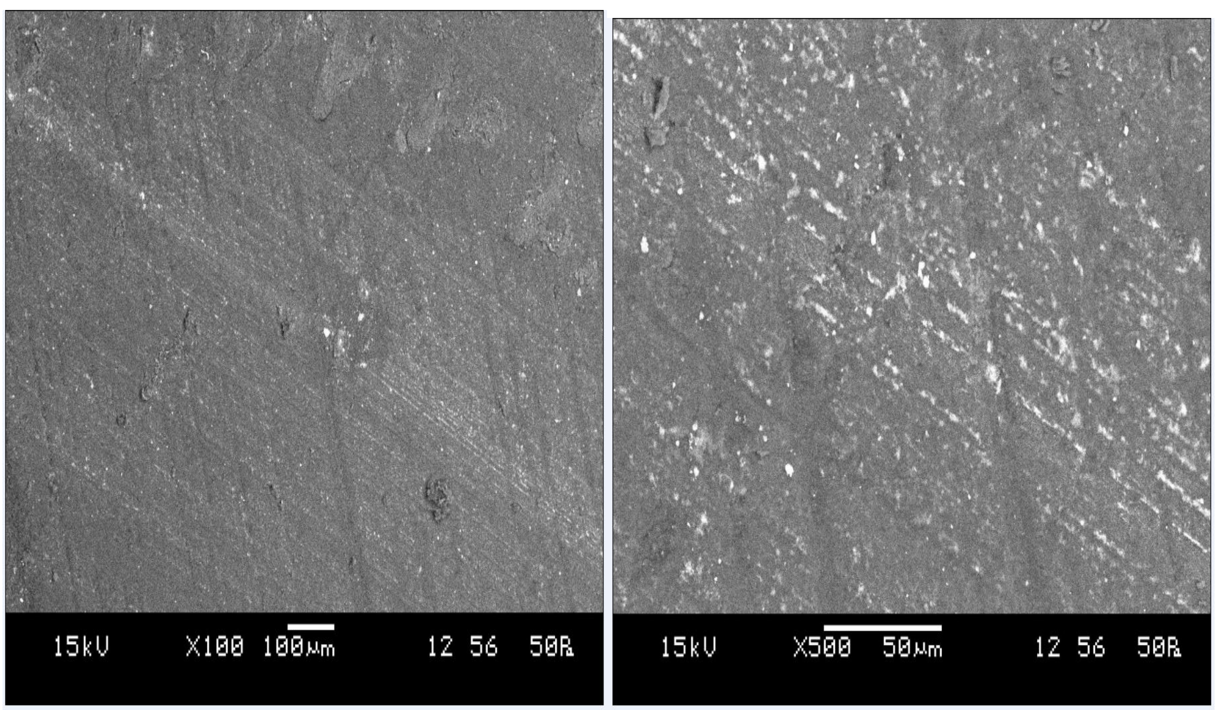
(H)Polyster-50N, 600 9-2



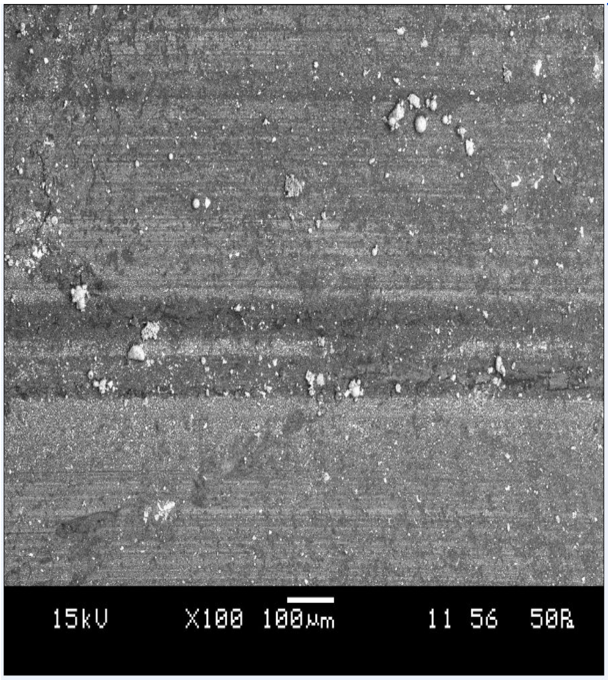
(I)Polyster+raw-10N, 200 rpm 12-2



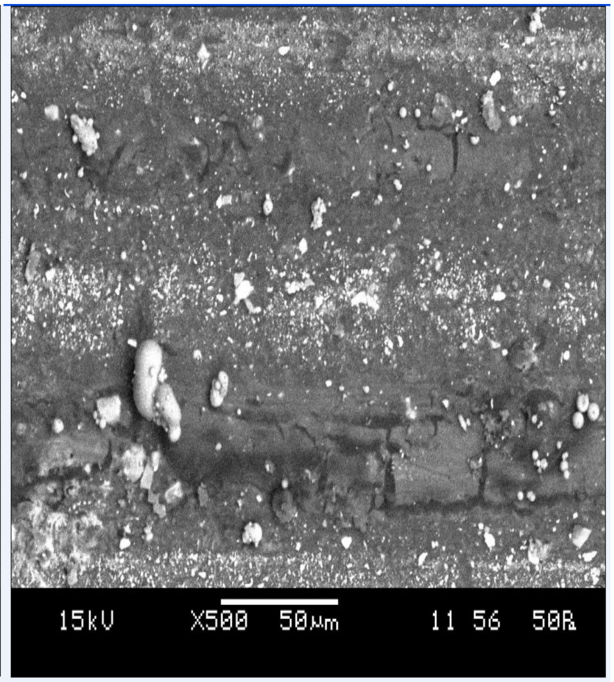
(J)Polyster+raw-10N, 600 rpm 10-2



(K) polyster+raw-50N,200 rpm 4-2



(L)Polyster+raw-50N, 600 rpm



11-2

Figures A,B,C,D,E,G,H,I,J,K and L show wear surface of neat epoxy(10N,200 rpm),neat epoxy(50N,600 rpm),feather reinforced epoxy composite(10N,200 rpm),feather reinforced epoxy composite(10N,600 rpm),feather reinforced epoxy composite(50N,200 rpm),feather reinforced epoxy composite(50N,600 rpm),neat polyester(10N,200 rpm),neat polyester(50N,600 rpm),feather reinforced polyester composite(10N,200rpm),feather reinforced polyester composite(10N,600 rpm),feather reinforced polyester composite(50N,200 rpm),feather reinforced polyester composite(50N,600rpm) respectively . Fig A and B shows wear occurs in certain planes in pure epoxy. Fig C, D, E and F shows the propagation of wear plane gets distorted and occurs in all directions due to presence of reinforcements. Fig G and H show wear planes in polyester. Fig. I, J, K, L the wear planes are not in particular direction, these plane occur in all directions due to presence of reinforcements.

5. Conclusions:

From the above studies it is cleared that;

1. The volumetric wear rate increases with increase in applied load and also with sliding distance.

2. Volumetric wear loss is minimum for feather reinforced polyester composite. This is due to the well bonding between matrix and reinforcement. It shows increase wear resistance as compared to feather reinforced epoxy composite.

3. Neat epoxy has more slide wear resistant than neat polyester.

4. The volumetric loss of feather reinforced epoxy composite and polyester composite varies parabolically.

6. References:

1. Schneider, J. P.; Myers, G. E.; Clemons, C. M.; English, B. W. Eng Plast 1995, 8 (3), 207.
2. Reinforced Plastics 1997, 41(11), 22.
3. Colberg, M.; Sauerbier, M. Kunstst-Plast Europe 1997, 87 (12), 9.
4. Schloesser, Th.; Knothe, J. Kunstst-Plast Europe 1997, 87 (9)
5. Nabi Sahieb. D, Jog. J. P, "Natural fiber polymer composites, a review", Advances in Polymer Technology, Vol. 18, No. 4, 351–363 ,1999
6. Yan Li, Chunjing Hu, Yehong Yu, "Interfacial studies of sisal fiber reinforced high density polyethylene (HDPE) composites", Composites Part. 2007 (in press)
7. Li Y, Mai Y-W, "Interfacial characteristics of sisal fiber and polymeric matrices", J. Adhesion. 82, pp.527–54, 2006.
8. FG. Torres, ML. Cubillas, "Study of the interfacial properties of natural fiber reinforced polyethylene", Polym. Test. 24, pp.694–8 2005.
9. D. Ray, B.K. Sarkar, A.K. Rana, N.R. Bose, "The mechanical properties of vinyl ester resin matrix composites reinforced with alkali-treated jute fibers", Composites Part A. 32,pp.119–27, 2001.
10. M.S. Sreekala, S. Thomas, "Effect of fibre surface modification on water-sorption characteristics of oil palm fibres", Compos. Sci. Technol. 63, pp.861–9, 2003.
11. Jeffrey W. Kock, "Physical and Mechanical Properties of Chicken Feather Materials", MS Thesis, School of Civil and Environmental Engineering, Georgia Institute of Technology, May -2006.
12. Fraser, R.D.B, Parry, and D.A.D, "The molecular structure of reptilian keratin", International Journal of Biological Macromolecules. 19, pp.207-211, 1996.

13. W.F.Schmidt, “Innovative Feather Utilization Strategies”, National Poultry Waste Management Symposium Proceedings, 1998.
14. J. Bitter, A study of erosion phenomena, part 1, Wear 6 (1963) 5–21.
15. I.M. Hutchings, Particle erosion of ductile metals: a mechanism of material removal, Wear 27 (1974) 121.