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Investigation of Wear & Friction Characteristics of Laminated Polymer Matrix Composite at Different Temperature

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***Abstract*— The aim of this project is the experimental investigation of the Friction and wear properties of polymer matrix composite such as unidirectional Glass –Epoxy (G-E) laminates are experimentally examined of three different fiber orientations, namely cross ply, symmetric ply, unidirectional ply , at different temperature conditions. These laminates are made by hand layup followed by compression molding. The wear behavior of these composite will be investigated by pin on disc apparatus which is a wear friction monitor machine. Against one standard EN31 steel disc under various sliding speed and loading, different temperature conditions and design of experiments approach using Taguchi's orthogonal arrays are used .Microscopic investigations of the worn surfaces are conducted to identify the operating wear mechanism and tribological behavior. From experimental test it found that wear rate is increases with increase in load of 50N,75N,100N. Disc rotating at 900rpm, 1100rpm, and 1300rpm at room temperature. But when test conducted at 50^{o}c, 75^{o}c different temperature conditions wear rate is increases with increase in temperature.**

Index Terms— Wear, friction, composites, polymer matrix composites, carbon –epoxy, glass –epoxy, pin on disk

I INTRODUCTION

Many polymer and polymer based composites are widely used for sliding couples against metals, polymers and other materials. However, where the contact is there, there is problem of friction and wear. The friction between polymers can be attributed to two main mechanism, deformation and adhesion. In this case, the deformation mechanism involves complete dissipation of energy in the contact area while the adhesion component is responsible for the friction of polymer and is a result of breaking of weak bonding forces between polymers and is a result of breaking of weak bonding forces between polymer and chains in the bulk of the material. In fact, triibologists often classify thermoplastic polymeric materials into three distinct groups according to their friction and wear behavior. Numerous nanoparticle used as oil additives have been investigated in recent years. Results show that they deposit on the rubbing surface and improve the tribological properties of the base oil, displaying good friction and wear reduction.

There are very good effect of using graphite content wear rates were decreased significantly .The field of tribology deals with design, friction, wear and lubricating surfaces, in relative motion . Polymers and their composites form a very important class of tribo-engineering materials and are invariably used in many mechanical components, such as gears, cams, wheels, impellers, brakes, seals, bearings, bushes, bearing cages etc., where adhesive wear performance in non-lubricated condition is a key parameter for the material selection . In most of these cases the materials are subjected to stringent conditions of loads, speeds, temperatures and hazardous environment. To combat these situations, composites should possess better mechanical and tribological properties Continuous carbon fiber reinforced polymer composites are increasingly being used in aerospace, marine, offshore, civil infrastructure, and automotive applications.

A. Problem Statement

To Investigation of Wear & Friction characteristics, tribo-mechanical behaviour of laminated polymer matrix composite at different temperature conditions and validates it by analytically and experimentally.

B. Objectives

- To Investigate Friction and wear characteristics of PMC laminates examined for three different fiber orientations at different temperature conditions.

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- To find out the Tribo- mechanical behavior of material from the effect of various loads, sliding velocities and different Temperature conditions have been determined.
- To study the phenomenon of failure of transfer film by making use of Scanning Electron Microscopy (SEM).
- To determine smaller is better signal to noise ratio for coefficient of friction and wear from the effect of material, load and sliding velocity by using MINITAB software.
- To determine best suitable material from the tested material under dry and temperature condition.

II .LITERATURE REVIEW

You song Sun et.al [1]. This literature review presents a broad review of the Special carbon fabric reinforced composites were fabricated with surface layers modified by carbon/PTFE hybrid fabrics. The tribological properties of this composite s under heavy loads were evaluated. There results showed that tribological properties of the composite were improved with increasing the PTFE content. The friction coefficient, volume wear and temperature rise of the composite with 6yarns of PTFE were reduced by 40%, 91% and 64% respectively in comparison with the composite without PTFE. After testing, PTFE could be observed over the entire wear groove surface, including the bottom.

Xinrui Zhang et.al [2] This literature review presents a broad review of the Carbon fabric/phenolic composites modified with potassium titanate whisker (PTW) were prepared by a dip-coating and hot-press molding technique, and the tribological properties of the resulting composites were investigated systematically using a ring-on-block arrangement under different sliding conditions. Experimental results showed that the optimal PTW significantly decreased the wear-rate.It are observed that the wear-rate increased with increasing applied load and sliding speeds.

Li Wenbin et.al [3] Carbon fabric/phenolic composites with different weave filaments counts were prepared by dip-coating and hot-press techniques, and then their mechanical and wet tribological properties were investigated based on the analysis of the three-dimensional surface profiles and the pore structures. Results show that the mechanical properties (elastic modulus, flexural modulus, tensile modulus, flexural strength and tensile strength) of the 3K carbon fabric/phenolic composites (Composite A) are better than thatof the 12K carbon fabric/phenolic composites (Composite B). The wear rate of Composite B is 39% greater than that of Composite A and thewear features of worn surfaces demonstrate the excellent wear resistance for Composite A. Based on theobservation of worn surface, the wear mechanisms are presented.

Hiral H Parikh et.al [4]. In the current article an inclusive literature survey on the tribological behavior of FRPCs in terms of friction and wear properties of composite materials is explored. The paper reviews the effects of different operating parameters and material parameters on wear rate and frictional behavior of FRPCs .The analysis reveals that operating parameters like sliding velocity, sliding distance, load, temperature and material parameters like a fiber volume fraction, orientation of fibers, fiber length, filler content, and effect of surface treatment have a significant effect on the tribological behavior of composite material.

Seyyedvahid Mortazavian et.al [5].This literature review presents a broad review of the many factors influencing cyclic deformation, fatigue behavior, and damage development in SFRPCs. These include micro structural related effects as well as effects related to loading condition and their service environment. Micro structural related effects include those related to fiber length, content and orientation, surface treatment, and failure mechanisms. Cyclic deformation and softening, viscous characteristics, and dissipative response used to characterize and model their fatigue damage behavior and accumulation are discussed.

N. Mohan1 et.al [6]. In this work an attempt was made to evaluate the mechanical properties and tribological behavior of glass fabric reinforced- epoxy (G-E) composites and silicon carbide filled glass fabric reinforced-epoxy (Sic-G-E) composites. The fabricated wear specimens were tested by using pin-on-disk test rig at various temperatures. The wear loss in both the composites increases with increase in temperature/applied load and under the same conditions the specific wear rate increases. However, silicon carbide particulate filled G-E composite exhibits lower wear rate with higher coefficient of friction as compared to virgin G-E composite.

Siddhartha et .al [7] In the current article an inclusive literature survey on the the investigations on modified mechanical and wear characteristics of cement kiln dust (CKD) reinforced homogeneous epoxy composites and its functionally graded materials developed for tribological applications. Mechanical properties of these graded composites are evaluated and compared with those of homogenously filled epoxy composites. The results found from the theoretical model so proposed are found to be in good agreement with the experimental values under similar test conditions. This study reveals that the presence of cement kiln dust particles enhances the sliding wear resistance of epoxy resin and the homogeneous composites suffer greater wear loss than the graded composites.

S.R. Chauhan et.al[8] In the current article an inclusive literature survey on the tribological performance of pure vinyl ester (V), glass fiber reinforced (GFR), SiC filled glass fiber reinforced vinyl ester composite under dry and water lubricated sliding conditions. Friction and wear tests were carried out with configuration of a pin on a rotating disc under ambient conditions the results showed that the coefficient of friction decreases with the increase in applied normal load values both under dry and water lubricated conditions. On the other hand for pure vinyl ester specific wear rate increases with increase in applied normal load under dry sliding condition and decreases with increase in applied normal load under water lubricated conditions

B. Suresha et.al [9] In the current article an inclusive literature survey on the Friction and dry sliding wear behavior of [0/90]8S and unidirectional (UD) oriented carbon-epoxy (C-E) composites has been studied using block-on-roller test set up. The dry sliding wear experiments were conducted for the following C-E composites namely [0/90]8, parallel and anti-parallel surfaces with respect to the sliding direction. The coefficient of friction and wear of the composites for two different loads and various sliding velocities have been determined. It was observed that the wear loss increases linearly with increase in sliding velocity/loads.

B. Suresha et.al [10]**.**In this particular investigation, carbon-epoxy (C-E) composite is compared with that of glass-epoxy (G-E) composites for tribological properties using a pin-on-disc set up. The tests are conducted by subjecting C-E samples sliding against a hard steel disc (62 HRC) under different sliding and loading conditions. This article highlights the friction and wear behavior of these composites run for a constant sliding distance, where in the C-E composites show lower friction and lower slide wear loss compared to G-E composites irrespective of the load or speed employed.

A. Summary from Literature Review

After studying the different research papers it is found that the tribological characterization of various fiber polymers has been carried out by many researchers. In the operating parameters most influenced parameters are load, sliding distance, sliding velocity, and ambient temperature while the material parameters are fiber length, fiber orientation, and fiber volume fraction. Along with this chemical and physical treatment, types of fillers and manufacturing techniques play an important role in friction and wear properties.

Most of all the research on composites have been carried out without finding the effect of high temperature and lubrication, different fiber orientation in laminated composites but in actual application temperature, lubrication, different fiber orientation in laminated composites might be involved so the experiments can be explored to find out the effect of temperature, lubrication, different fiber orientation in laminated composites on the wear rate.

III.EXPERIMENTAL DETAILS

A. Materials

In the present study uni-directional glass fibers reinforced epoxy resin (G-E) composites are considered. The type of epoxy resin used here is clear-light liquid LY 556 and the hardener is clear liquid HT 951 both supplied by M/s Sthenos composites" MIDC chakan, Pune

India. The epoxy resin is mixed with the hardener in the ratio 70:30 by weight.

B. Laminated Sheet Fabrication

The laminates were made by hand layup followed by compression molding. Unidirectional stitch bonded glass fabric of diameter of about 8 micron to 20 micron was used in G-E composite. The glass fiber surface was treated with coupling agent to improve Adhesion between the fiber and matrix.

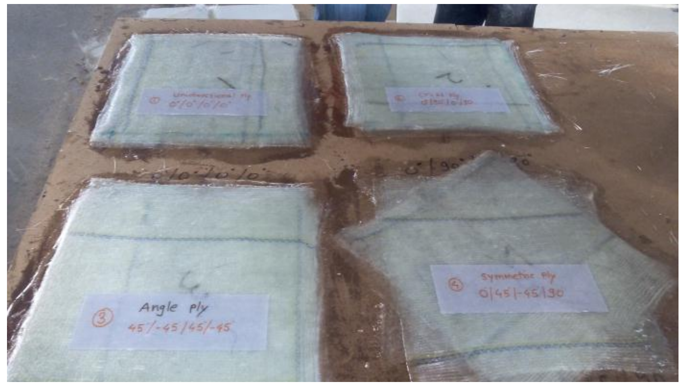

Fig.3.1: laminated sheets made by hand layup

The glass fabrics were stacked in longitudinal and transverse directions alternately i.e. Angle ply(45/-45)2s, cross ply (0/90)2s , Symmetric ply (0/45)2s, Unidirectional(0/0)2s ,. Four layers of fabrics were used to obtain the approximate laminate thickness of 5.0 mm. The panels were fabricated using a well known hand layup technique, followed by autoclave curing facility. The Glass epoxy laminate was cured in an autoclave according to the manufacturer's prescribed cure cycle, and post-cured as necessary. The dry sliding wear test samples of size 12*12*5.0 mm were prepared from the laminate using a diamond tipped cutter. All these panels manufacturing did at "Sthenos composites" MIDC chakan, Pune.

C.Experimental setup

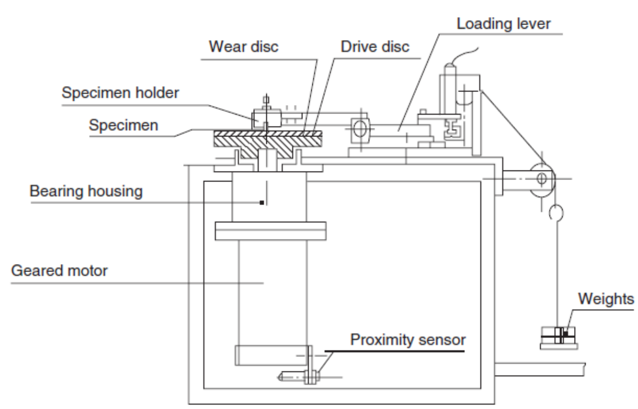

Fig.3.2: Experimental Setup of Pin on Disc Tribometer

A high temperature pin-on-disc (HT-POD) setup was used for the sliding wear tests as per ASTM-G99 standard (Fig 3.2). The cut sample from fabricated composite laminates of 12mm x 12 mm x 5 mm was fabricated and fitted in the pin holder mounted in the HT-POD lever-arm such a way that which comes in contact with a hardened alloy steel disc of the machine. The hardness value of the EN-32alloy steel disc is 55 HRC and surface roughness (Ra) of 0.65µm. the test was carried out at normal load of 50N, 75N ,100N .Speed of rotating disc is 900rpm,1100rpm,1300rpm and at varying temperatures viz., 30^{o}c, 50^{o}c, 75^{o}C. For every sample the surface is cleaned with a soft paper soaked in acetone and compressed air before and after testing. The specimen weight is recorded using digital electronic balance 0.1 mg accuracy. The difference between initial and final weight of the specimen was a measure of slide wear loss. The frictional force is measured by attaching a force transducer on the machine. The friction coefficient was recorded continuously and gets displayed on a computer interfaced with the high temperature pin-on-disc (HT-POD) machine.

Specifications of PIN and DISC Tribometer:

- Pin size =3,6,8,10&12 mm diameter and 30 mm long
- Disc size= diameter 165 mm and 8 mm thick
- Wear track diameter= min 50 mm to max 100 mm
- Disc rotation speed=200 rpm to 2000 rpm
- Sliding Speed Range=0.5 to 10 m/sec
- Normal load= minimum 5 N to maximum 500 N
- Frictional force= 0 to 200 N
- Temperature= minimum ambient to maximum 400^o C
- Power= 1phase, 230 V, 16A, 50 Hz

D. Method To Calculate Wear Factor

The contact between two sliding surfaces, because of the inevitable friction generated in the contact zone, results in certain wear whose magnitude depends on load, speed and time of sliding contact.
Theoretically, between these parameters and the resulting wear exists a relation proportional to

W=KFVT

Where, W= wear volume in mm3
F= Frictional force in N
V= Sliding speed in m/sec
T= Time in sec
K= wear factor in mm3/Nm

Contact pressure (P) and the sliding speed (V) strongly influence material wear rates. Each material has a PV limit. Above this limit, a material will fail. The PV limit is however more conceptual than practical. Higher PV values indicate an ability to operate under the heavy loads and faster surface velocities. An increase in pressure increases the wear rate and decreases the friction, whereas higher sliding speed increases both wear and friction.

IV. Result And Discussion

Investigation of Tribological properties such as coefficient of friction , wear rate of laminated polymer matrix composites of different fiber orientation such s Cross ply , Symmetric ply , Unidirectional ply at room and different temperature conditions are studied on Pin on Disc Tribometer and Pin flat surface placed normal to rotating disc surface. Results are plotted as following.

A. Cross Ply

1) Load: 50N Speed: 900rpm Temp:30^o c

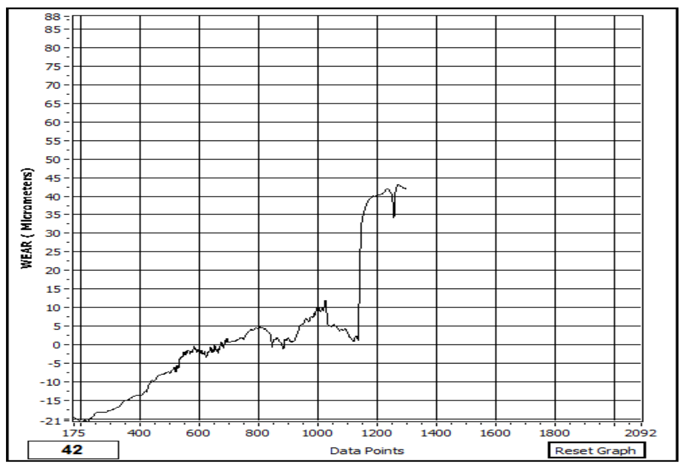

Fig 4.1: Wear Vs Time at 900 RPM.

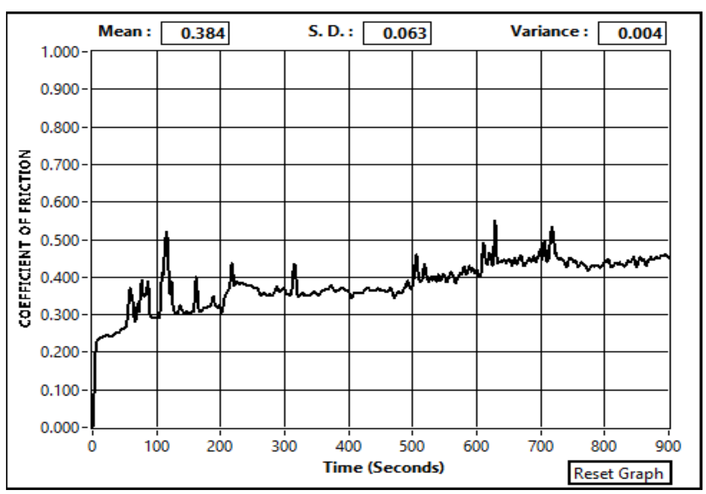

Fig 4.2: Coefficient of friction Vs Time

Tribological properties such as coefficient of friction, wear occurred are plotted against the time of 30 minutes. From fig.4.1 & 4.2 shows that's Cross ply pin material shows wear up to 42 µm. and coefficient of friction rise up to 0.384

2) Load: 50N Speed: 900rpm Temp :50^{o}c

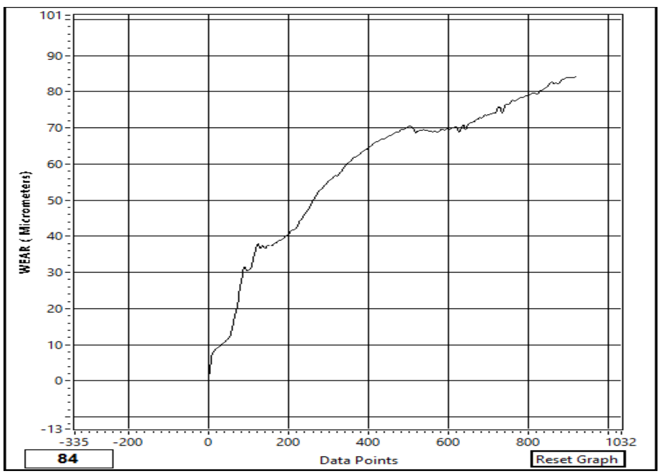

Fig 4.3: Wear Vs Time

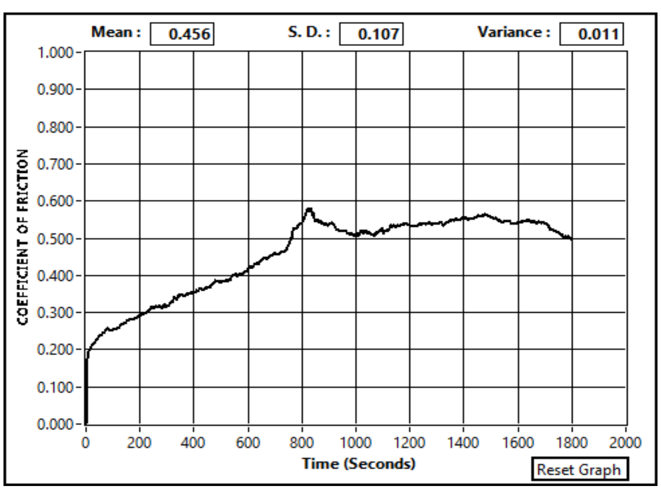

Fig 4.4: Coefficient of friction Vs Time

Fig 4.3 & 4.4 Graphs shows that's Cross ply pin material shows wear up to 84 µm. and coefficient of friction rise up to 0.454. From this we observed wear rate is increased when temperature increases.

B. Symmetric ply

1) Load: 50N Speed: 900 rpm Temp: 30oc

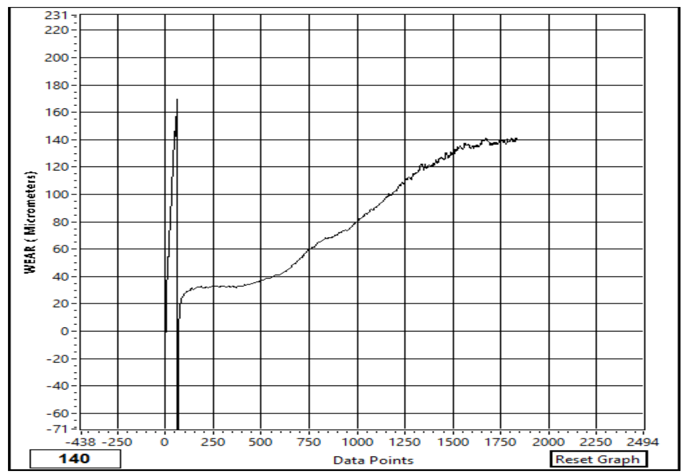

Fig 4.5: Wear Vs Time

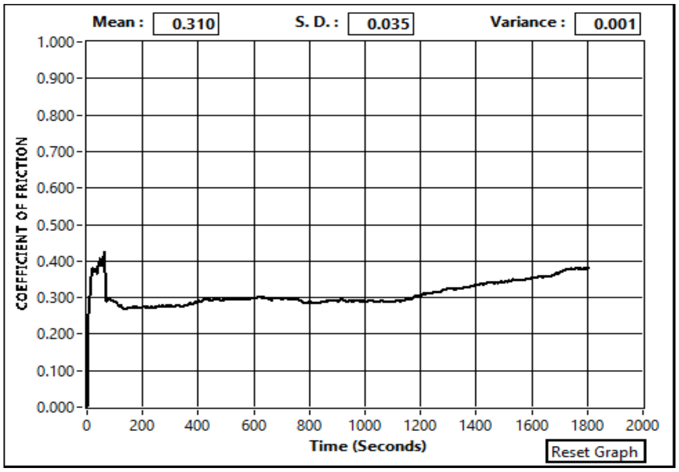

Fig 4.6: Coefficient of friction Vs Time

Fig 4.5& 4.6 Graphs shows that's Symmetric ply pin material shows wear up to 140 μm. and coefficient of friction rise up to 0.310.

2) Load: 50 N Speed: 900 rpm Temp: 50^{o}c

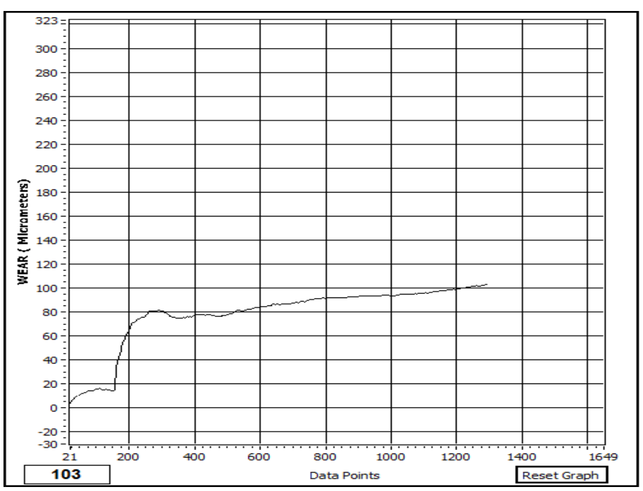

Fig 4.7: Wear Vs Time

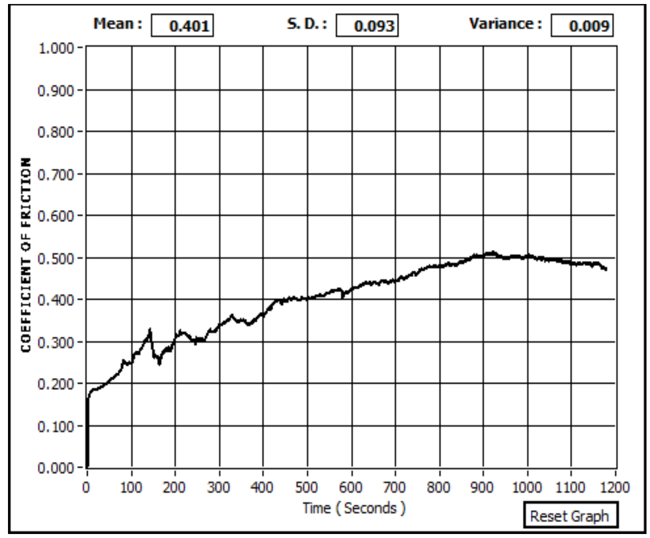

Fig 4.8: Coefficient of friction Vs Time

Fig 4.7 & 4.8 Graphs shows that's Symmetric ply pin material shows wear up to 103 μm. and coefficient of friction rise up to 0.404

3) Unidirectional ply

1) Load: 50N Speed: 900rpm Temp: 30^{o}c

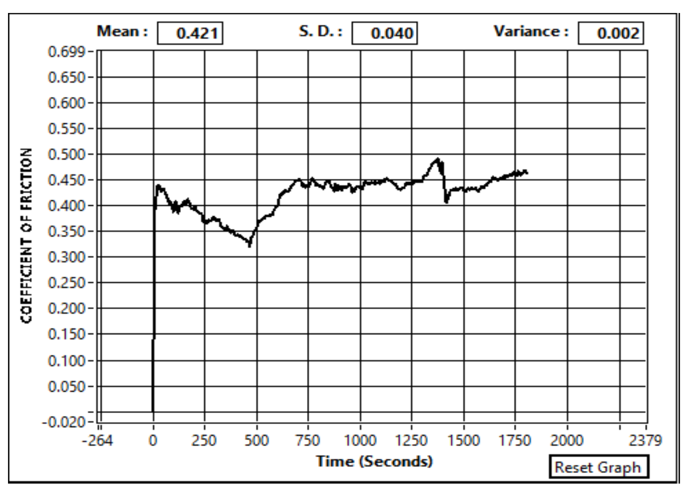

Fig 4.9: Coefficient of friction Vs Time

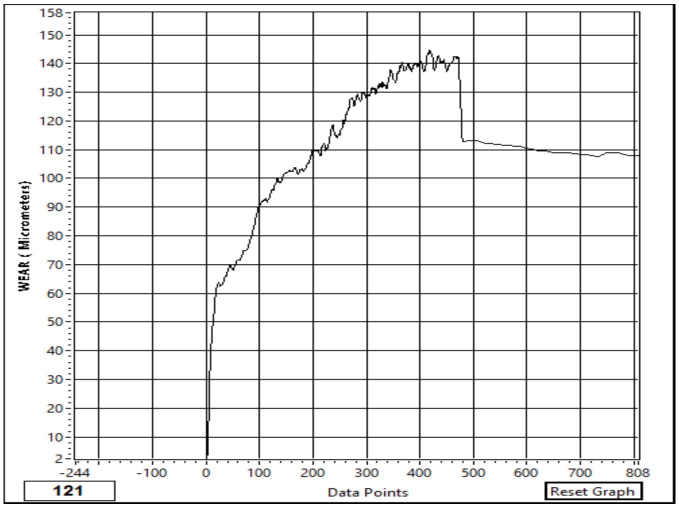

Fig 4.10: Wear Vs Time

Fig 4.9 & 4.10 Graphs shows that's unidirectional ply pin material shows wear up to 121 µm. and coefficient of friction rise up to 0.421. Above graphs indicate that wear rate high as compare to other two combinations i.e cross ply and Symmetric ply.

2) Load: 50N Speed: 900rpm Temp: 50oc

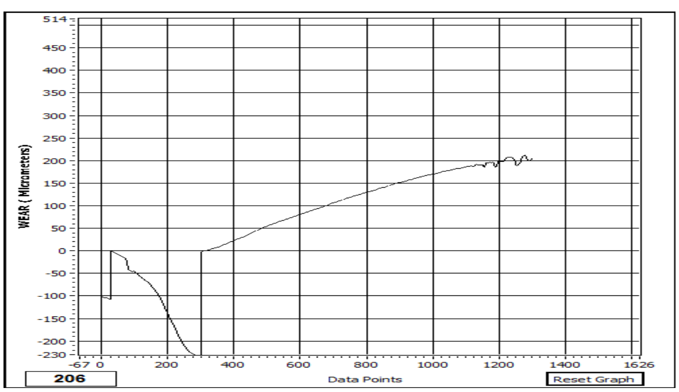

Fig 4.11: Wear Vs Time

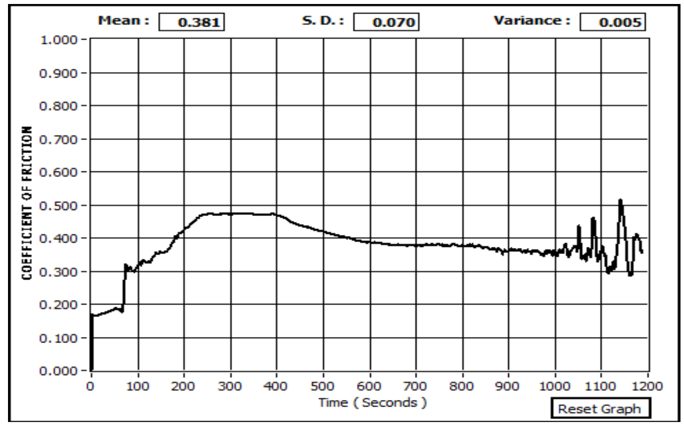

Fig 4.12: Coefficient of friction Vs Time

Fig.4.11 & 4.12 Graphs show wear rate is increased with increase in temperature.

Graphs shows that's unidirectional ply pin material shows wear up to 206 µm. and coefficient of friction rise up to 0.381

The following results are obtained from of the experimental investigation.

Sr.no	Material	Load (N)	Rpm of disc	Temp (°C)	Wear (µ)	Cof
1	Cross Ply	50	900	30	42	0.384
		50	900	50	84	0.454
2	Symmetric ply	50	900	30	140	0.312
		50	900	50	103	0.404
3	Uni.Ply	50	900	30	121	0.421
		50	900	50	206	0.381

V. CONCLUSION

1) The wear rate is increases with increase in load which varies from 50N, 75N, 100N For cross ply, symmetric ply, unidirectional ply at room temperature.

2) The increase in temperature from 30°C, 50 °C, and 75 °C leads to a reduction in coefficient of friction at high load of 100N and it causes a increase in wear.

3) The wear rate of unidirectional orientation ply is very high (221µ and 206 µ) than cross ply and symmetric ply at different load and different temperature conditions.

4) The wear rate of symmetric ply is low as compare to other orientations Ply at different load and different temperature conditions.

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