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Experimental Studies for Accessing the Influence of Micro-Dimple Area Density on Tribological Performance of Mating Contacts

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ABSTRACT

The present research has been done to investigate the influence of the relative motion of a plane surface with the other having micro-circular dimples throughout the contact. Using pin-on-disk setup, experiments have been carried out to study the influence of micro-dimple area density on friction and specific wear rate at the interface of two materials. Circular dimples are distributed in spiral array on the disk face. Based on the experiments, better tribological results have been achieved in the starved boundary lubrication mode.

Keywords: *Micro-Circular Dimples; Pin-On-Disc; Mating Contact; Spiral Array.*

1.0 Introduction

Existence of controlled dimple on mating surfaces reduces the friction and improves the tribological properties of the interface. Recently researchers [1-4] have provided more thrusts on improving the tribological issues using the surface engineering as a tool. Surface texture for friction reduction comprise of a flat surface interrupted by local micro-dimples.

It has been established by researchers that shallow micro-dimpled surface generates innumerable tiny hydrodynamic bearings, which separate the mating surfaces. Moreover, micro-dimples act as oil reservoirs and wear debris/contaminants trapping pits, which greatly contribute in enhancing the tribological performances of contacts even during the existence of mixed/boundary lubrication. Effective lubrication at the interface is influenced by many parameters such as surface roughness, dimple depth, dimple area density, dimple shape, and lubricant properties in addition to operating parameters.

Therefore, the objective of this paper is to explore the influence of dimple area density on the friction and wear behaviors of the contacts under various operating conditions.

2.0 Experimentation

2.1 Specimen of disc, pin and lubricating oil

Specimen of mild steel plate of 165 mm diameter and 8 mm thick has been taken as shown in Fig.1a for experimentation. Surface grinding and lapping fabrication processes has been performed on it to reach up to the level of surface roughness of 0.2 to 0.3 micrometer root mean square value and checked by surface roughness tester.

Cylindrical mild steel C-50 pin of diameter 12 mm has been taken for test on mild steel circular plate as dimensions shown in Fig.1b. The circular pin face has labeled and checked by rubbing on soft paper to remove debris and its flatness by ink impression on paper respectively the length of pin is about 30 mm, and diameter is 12 mm. The 26 mm length of pin is rigidly clamped and only 4 mm remains out in fixture for test on disc so that bending may be minimized and neglected during evaluation of tribological properties.

The lubricating oil (20W40) has been used which have the following characteristics measured in laboratory by true density meter, specific gravity meter and kinematic viscosity meter are 0.89036 g/cm3, 0.8912 and 120.79248 mm2/sec at 40°C and atmospheric pressure as per ASTM D-4052, D-287 and D-445 respectively.

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Fig 1a: Mild Steel Plate

2.2 Specimen of wear test rig

The wear test rig as shown in Fig. 2a and the specification in Table 1 has a motor that rotates with different speed based on rheostat and the speed may be fixed as desired between the ranges 200 to 2000 rpm of speeds.

A horizontal plate fixture is attached over which specimen of disc is bolted at four points. Speed detector and wear measurement probe is attached on it.

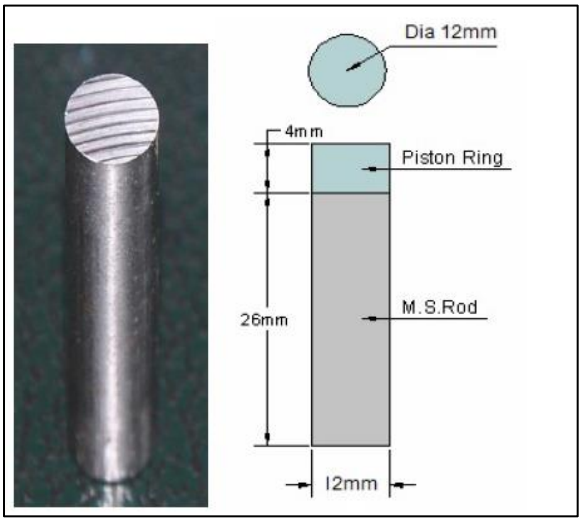
Loading is done on pan that have horizontal platform supporting the direction of gravity. The applied direction of force is transmitted through wire and pulleys arrangements.

Bell-crank mechanism with uni-leverage is used and force detector probe is used at the side to determine the sheer friction force. Following are specification of wear test rig.

Table 1:

Details		Description	Remarks
Top specimen (mm)	Pin	Dia 3,4,6,8,10 & 12	Material; Ms
Bottom specification (mm)	Disc	Diameter 165	Material: Ms
		Thickness 8	
Speed (rpm)	Disc	Minimum 200	
		Maximum 2000	
Frictional force (N)	Between pin & disc	0 to 200	

Fig 1b: Cylindrical mild steel C-50 pin



2.3 Dimples calculations

The minimum diameter of pin is 3 mm as per specification of test rig so radial distance have been grouped in set of 3 mm ranging from radius 10-70 mm on disc. Again the middle of those three have been considered for calculating number of dimples required to be fabricated on disc.

At considered radius having circumferential distance has been divided by required 1 mm, 2 mm, 3 mm and 4 mm pitches to know the number of dimples.

So the four plates have been prepared of 420 microns for analysis of minimum coefficient of friction. The dimples are prepared in such a way that the minimum diameter of pin was taken in consideration of 3mm. The radial distance has been taken in interval of one millimeter. The distribution of dimples along circumferential distance is taken according to the required pitch between two dimples.

For continuous three millimeter set of radial distance, the angle between two dimples is divided into three parts. The distribution of dimples starts from reference line for the first circumferential distance.

For the second circumferential distance in the same set of three radial distances, dimples starts from second angle. The third circumferential distance corresponding to third radial distance in the same set, dimple starts from third angle.

In this way all the circumferential distance corresponding to set of three radial distances, dimples are formed.

2.4 Specimen of disc with dimples

The dimples have been fabricated using chemical etching process for different disc with the different pitches. Drawings have been made by using Catia software as shown in Fig. 3 as follows:

Fig 2: Schematic Diagram of Pin on Disk Test Rig

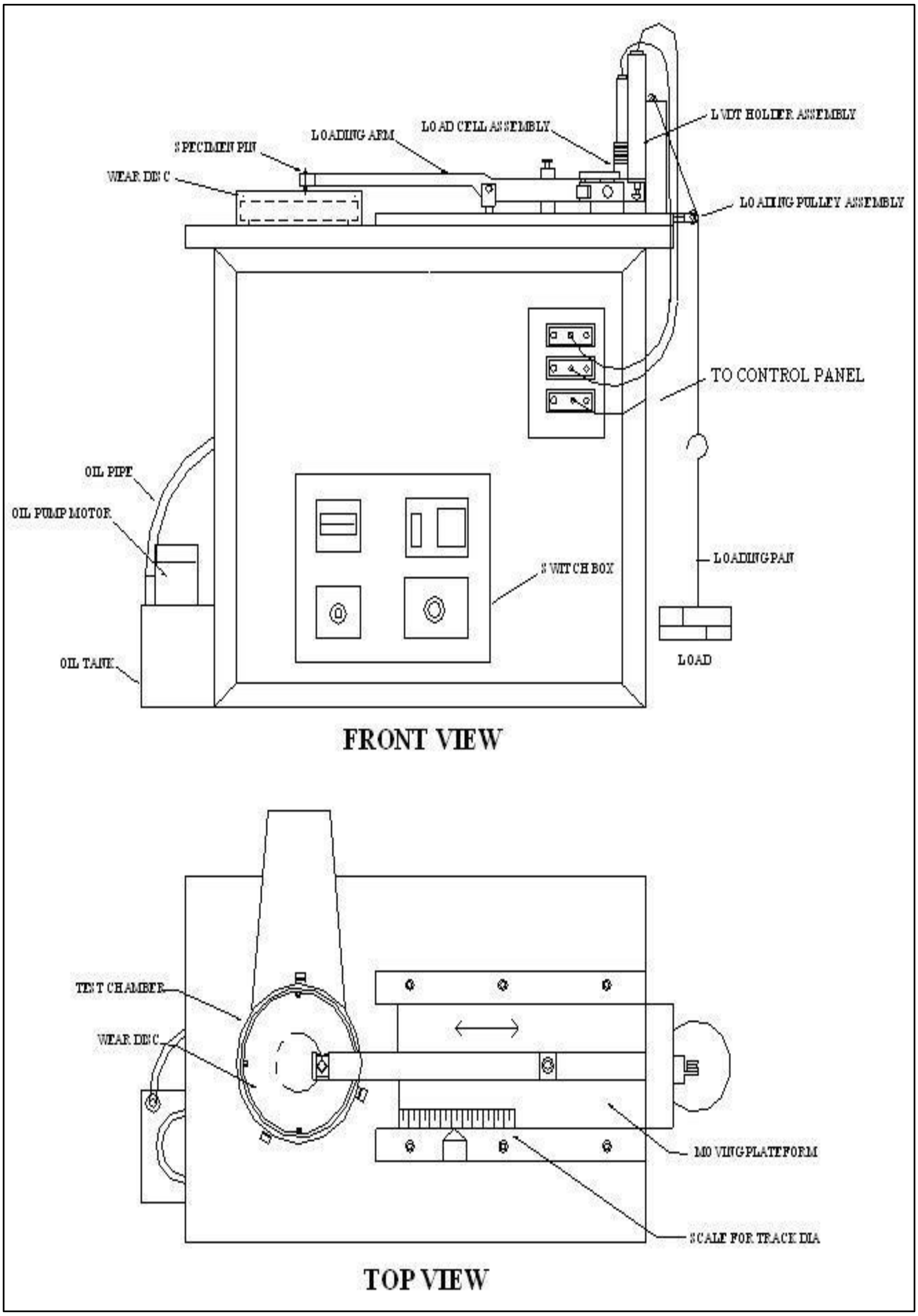


Fig 3a: Dimples of 420 Micrometer Diameter, Pitch 1 mm Along Circumferential Distance

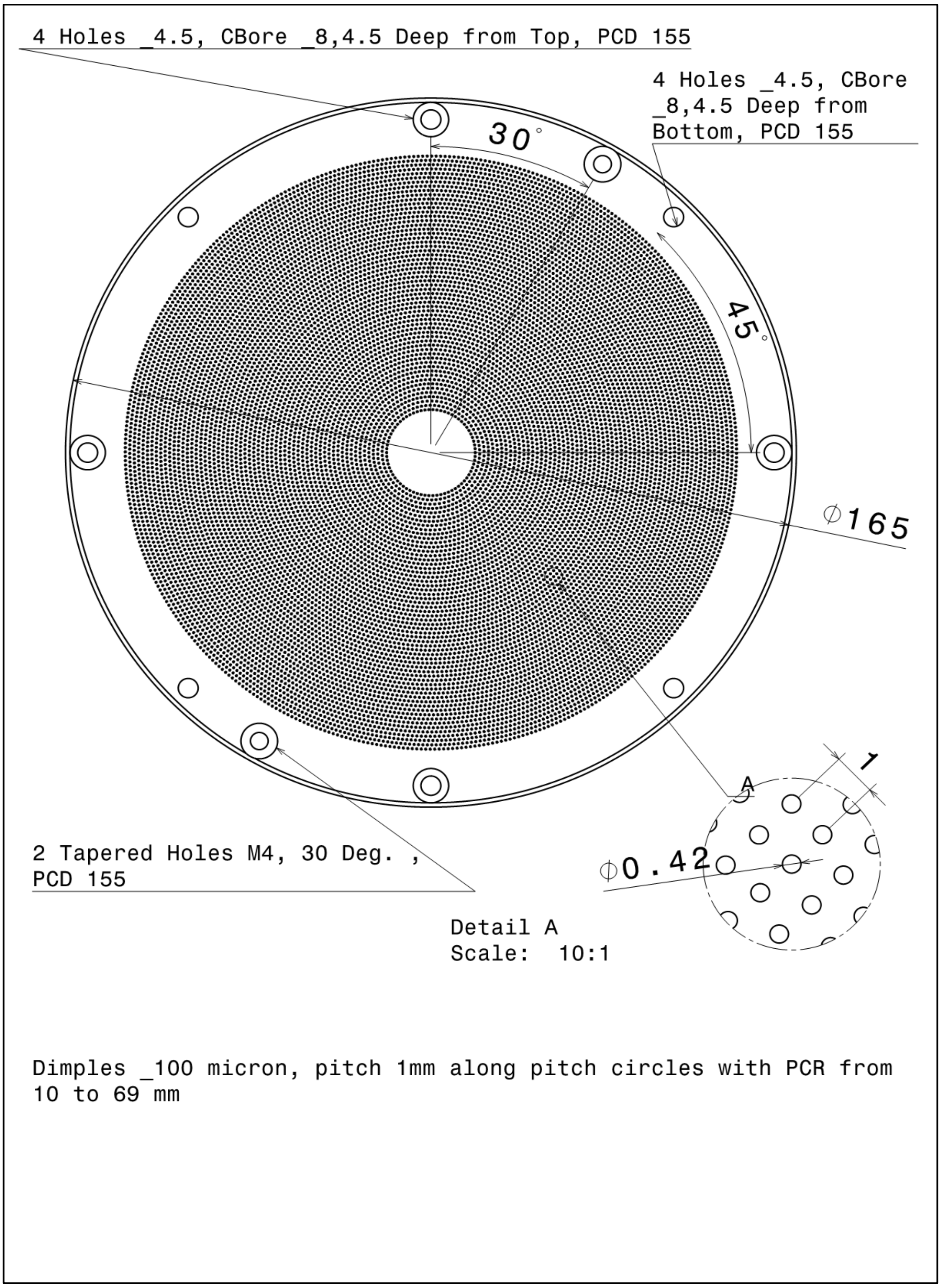
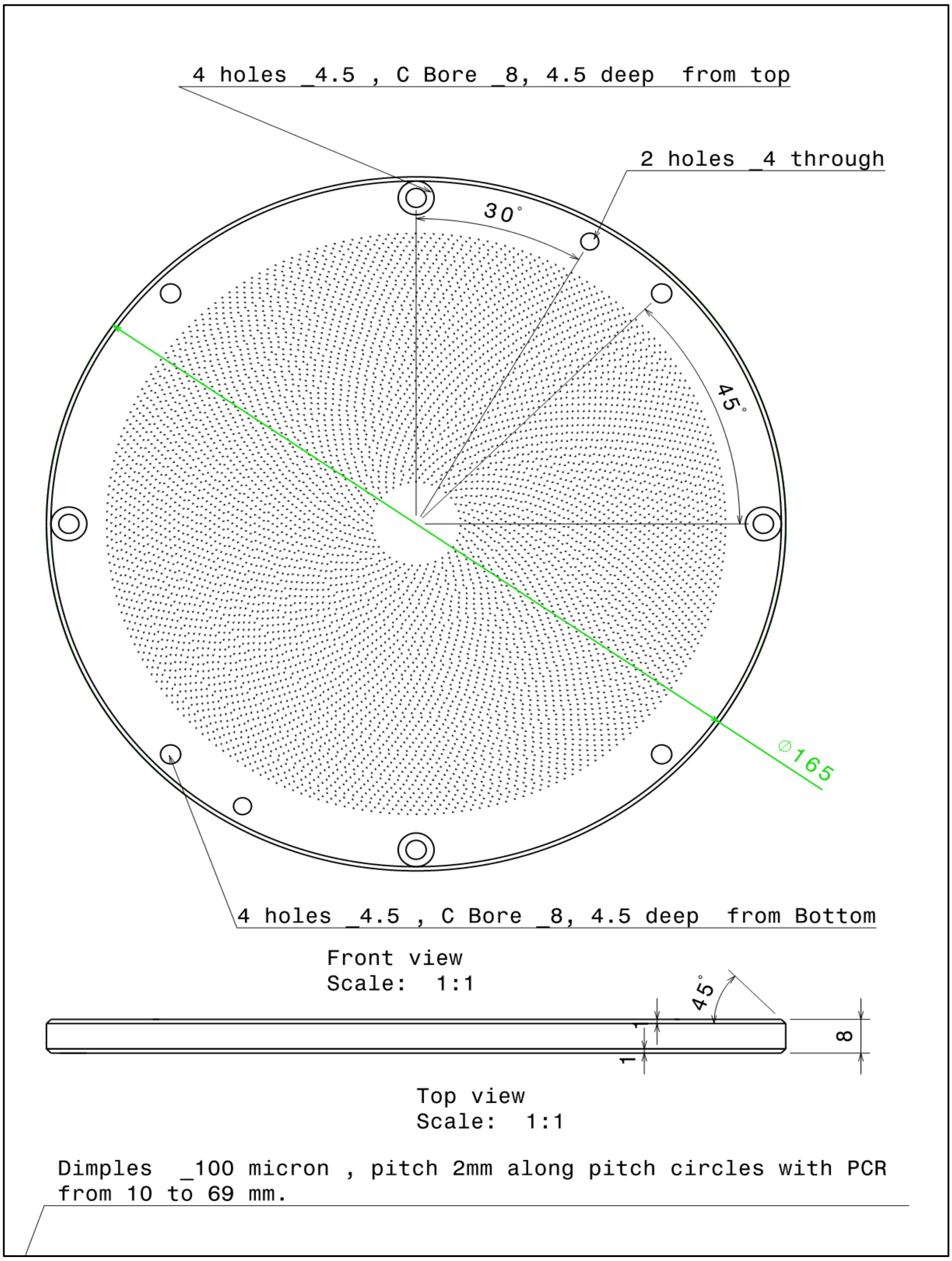


Fig 3b: Orthographic Drawing of Test Plate with Dimples of 420 mm Diameter and having Pitch 2 mm



For determining of the friction and wear at the interface formed between the pin end and disk face and worn disc and pin figures have been shown in Fig. 4. Both disk and pin are made of mild steel (C-50). The end faces of mating bodies have been lapped to the roughness of RMS to around 0.2 □m. The face of disk is textured in the pattern as shown in Fig.1. Circular micro-dimples of diameter of 420 μm and depth of 200-250 μm are created by chemical etching process on mild steel disk.

Tribological studies are conducted for the loads characterized by pressure varying in the range of 0.4- 1.4 MPa at sliding speeds 0.5-10 m/s (equivalent to 200 –2000 RPM).

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Fig 4a: Disc with Elaborated Part

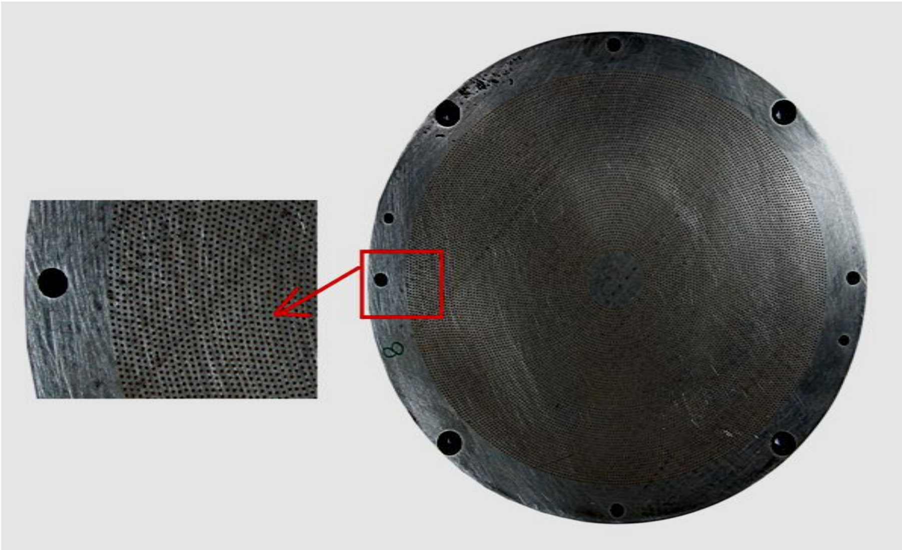
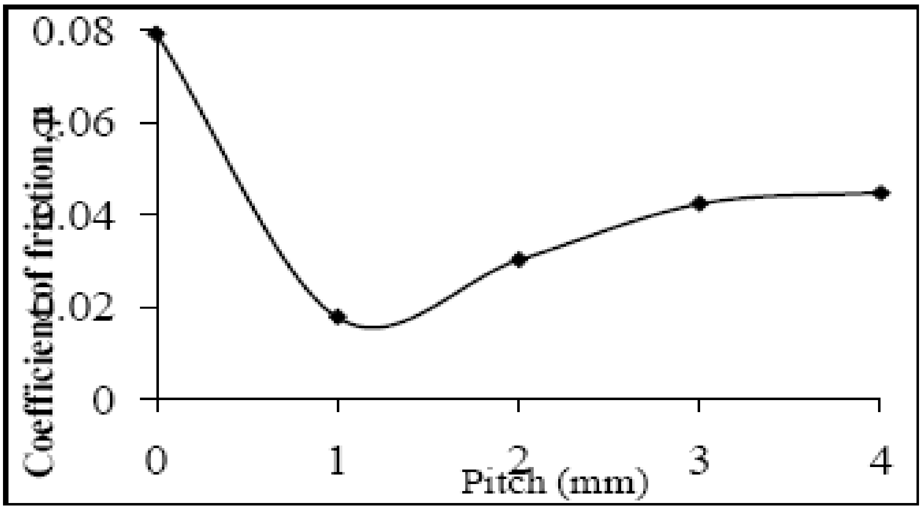


Fig 4b: Disc with Worn Track

3.0 Results and Discussions

Typical trends of friction coefficient μ at different sliding speeds are plotted in Fig. 5 at load of 118 N for starved lubrication. Dimples on the contact surface of disk having pitch 1mm improves the tribological performance immensely in comparison to disks having pitches 2, 3, and 4 mm.



A plane and four dimpled disc having pitch 1 mm, 2 mm, 3 mm and 4 mm has been taken for determining of coefficient of friction between pin and disc.

Experiments have been done by applying 118N (12 kg) load, 110 mm diameter of the disc, running at 500 rpm and pin has diameter 12 mm by applying lubricant having properties shown in table. Also the dry frictional coefficient between plain disc and pin is 0.233.

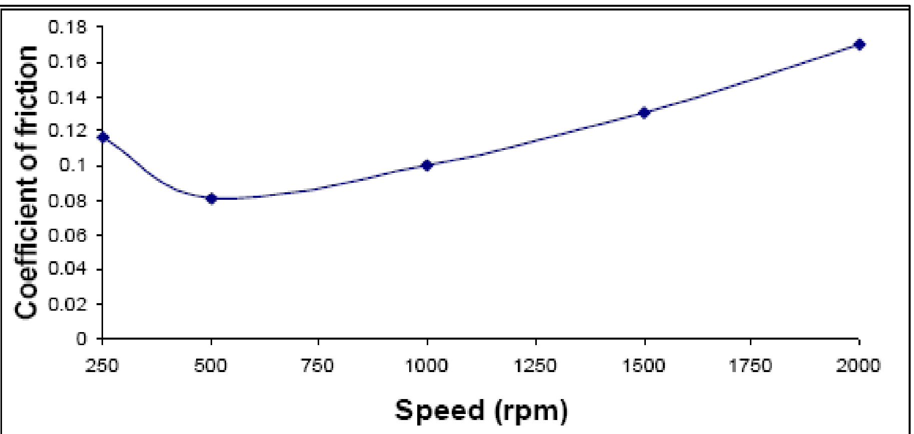
The graph shown in figure, plane disc or zero dimples has maximum value of order 0.079. Where as dimpled have 0.0178, 0.072, 0.042 and 0.032 corresponding to disc having pitch 1 mm, 2 mm, 3 mm and 4 mm respectively.

The plate having pitch 1 mm has minimum coefficient so considered for experiment.

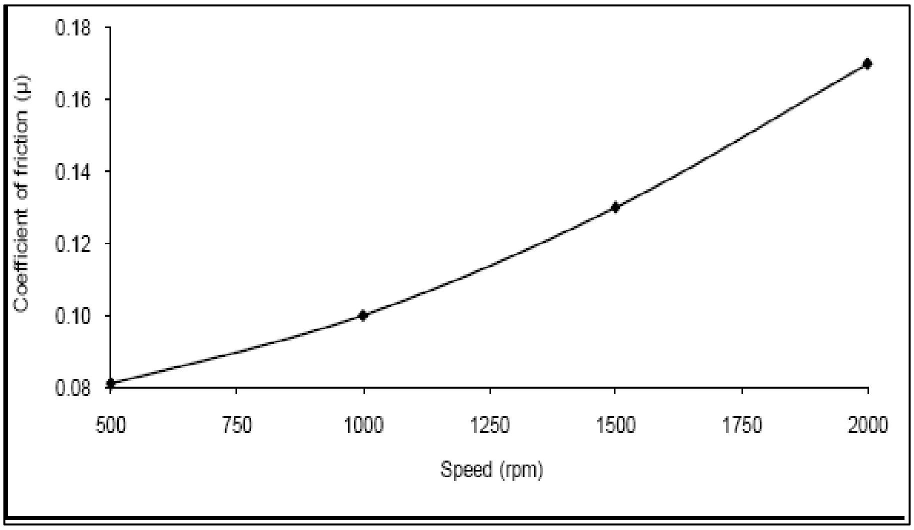
The disc has been lubricated only once during starting of experiment. The experiment has conducted at different rpm by keeping the load of 12kgf constant for 2400 second at diameter 110 mm.

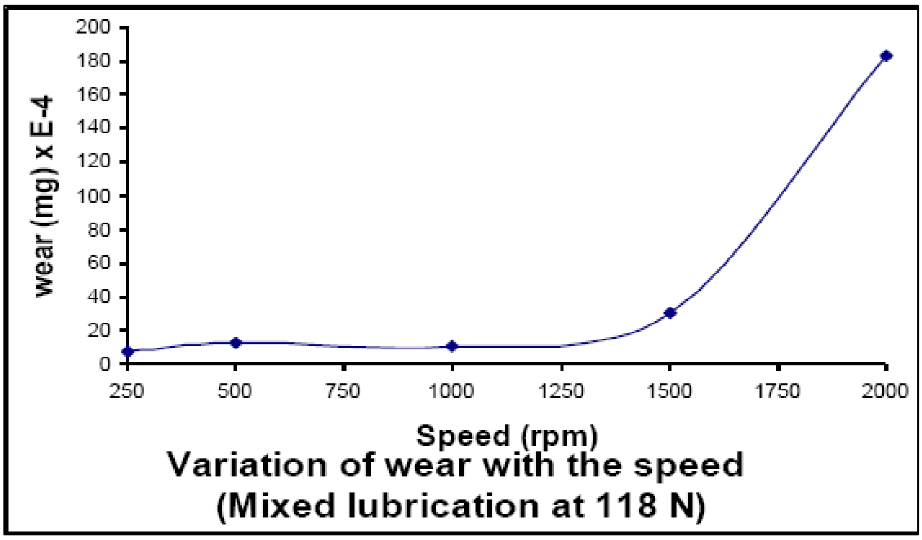
The frictional force with respect to different rpm has been read to plot variation of coefficient of friction vs load as shown in fig.

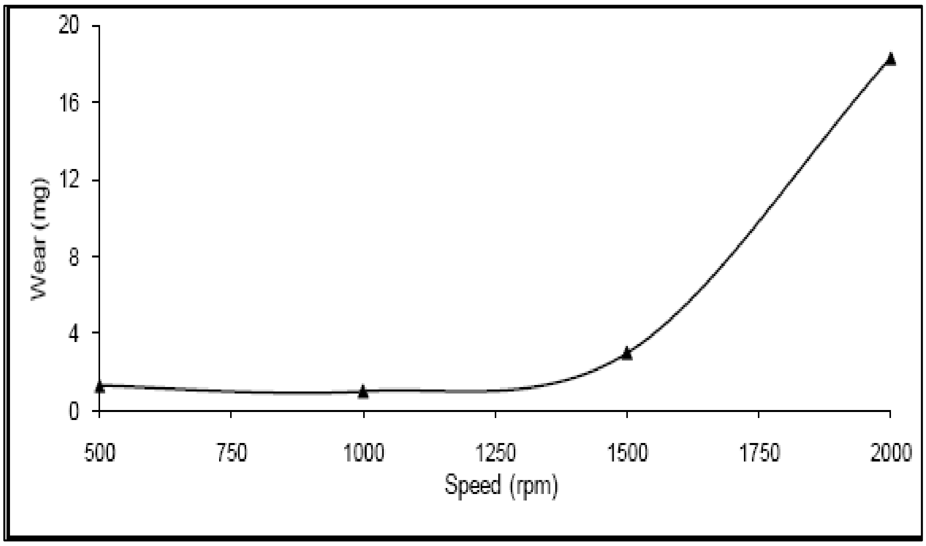
It has been observed that coefficient of friction initially decreases and after that it increases linearly with speed. There is no wear as shown by wear characteristics in fig. leaving last part where rapid grouth of wear take place.



Variation of coefficient of friction with speed (Mixed lubrication)

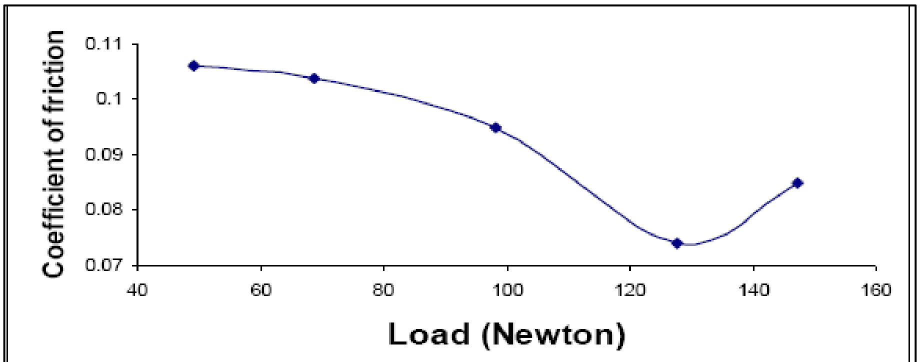

0.18
0.16
0.14
0.12
0.10
0.08
Coefficient of friction (μ)
500
750
1000
1250
1500
1750
2000
Speed (rpm)


wear (mg) x E-4
200
180
160
140
120
100
80
60
40
20
0
250
500
750
1000
1250
1500
1750
2000
Speed (rpm)
Variation of wear with the speed
(Mixed lubrication at 118 N)

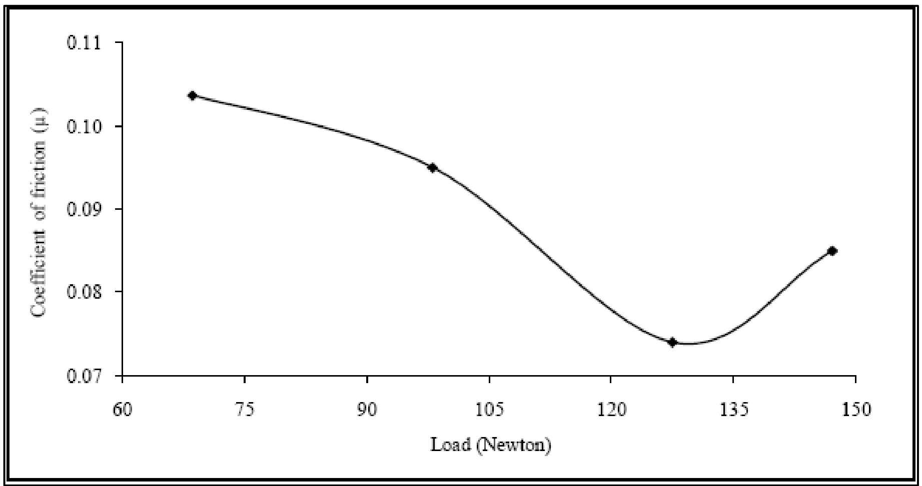

Wear (mg)
20
16
12
8
4
0
500
750
1000
1250
1500
1750
2000
Speed (rpm)

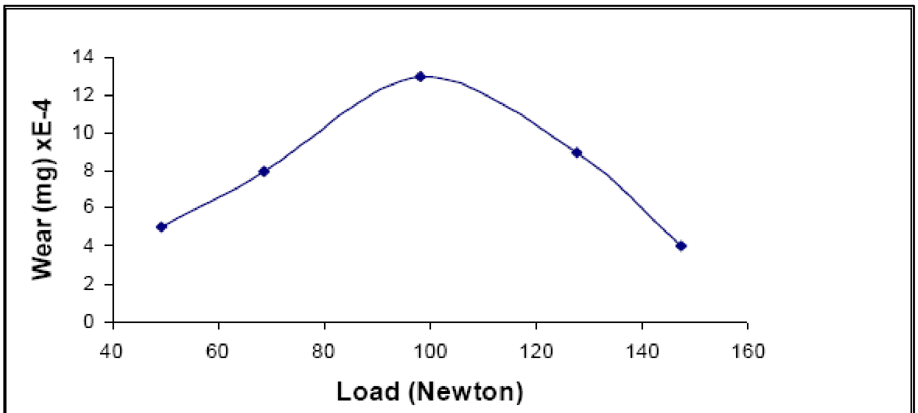
The variation coefficient of friction with respect to load is shown in fig for mixed lubrication. It decreases with load and at last it takes positive slop.

Whereas wearing of material shows that initially it increase and after that it reduces.



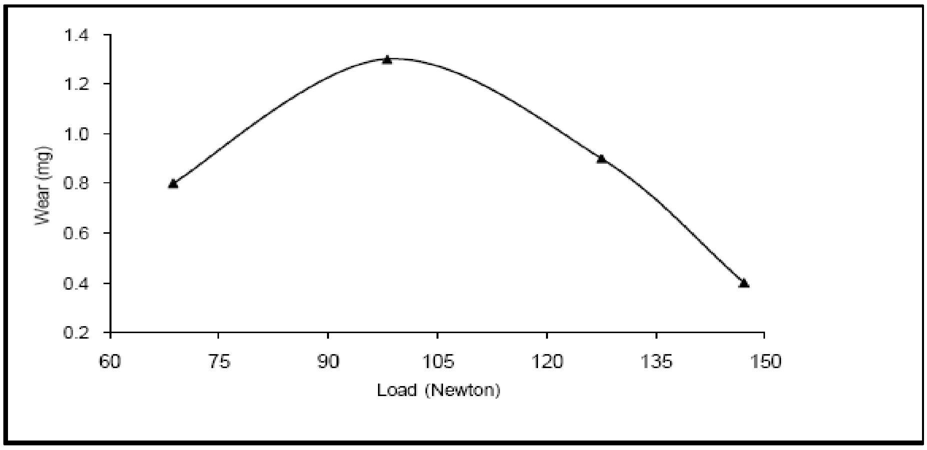
Variation of coefficient of friction with load
(Mixed lubrication at 1000 rpm)

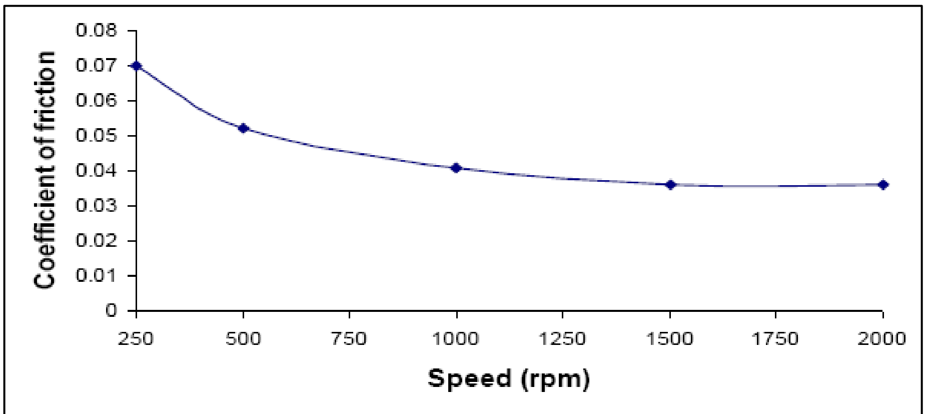




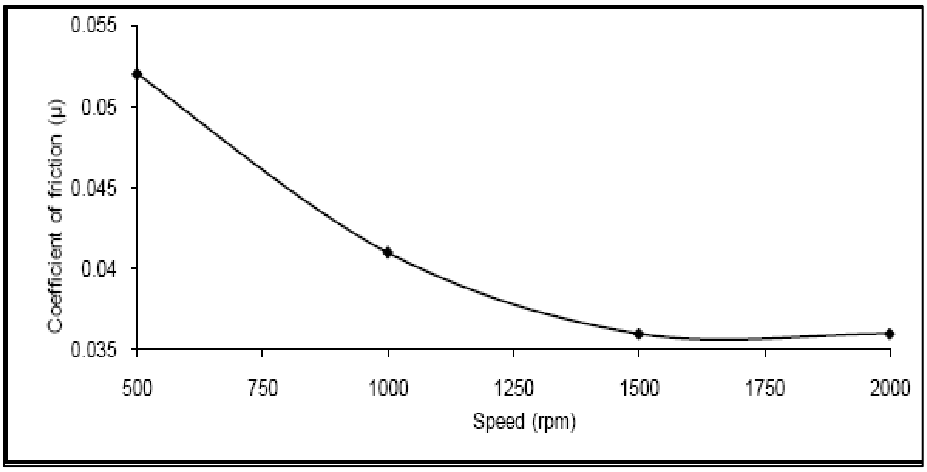
Variation of wear with load
(Mixed lubrication at 1000 rpm)

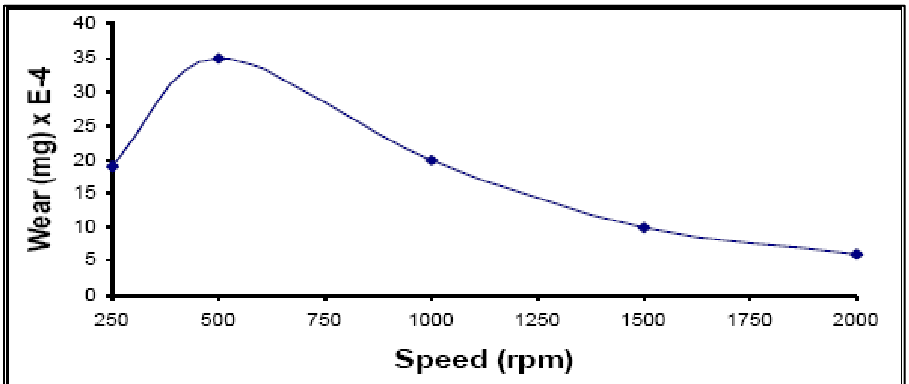
The experiment has been carried out with continuous flow of lubricating oil at the interface of pin and disc to form hydrodynamic lubrication. The load has been kept constant of 12kgf. And the speed has been varied. It has been observed that coefficient of friction continuously decreases with speed and after certain period it remains constant at minimum value nearly 0.03. The wear increases for very short period and after that it decreases continuously to become constant.



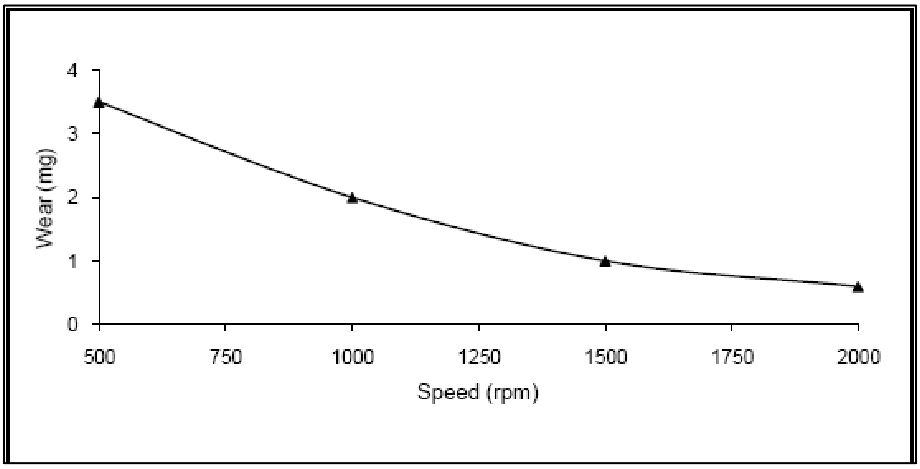


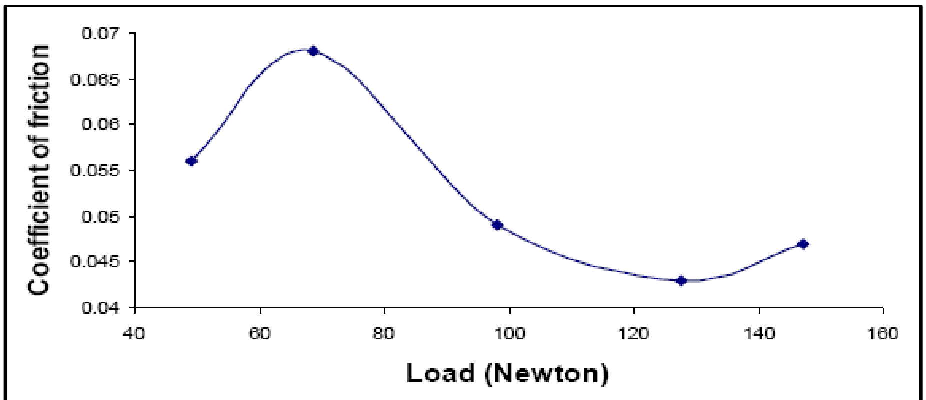
Variation of coefficient of friction with speed (Hydrodynamic lubrication at 118 N)





Variation of wear with speed (Hydrodynamic lubrication at 118 N)



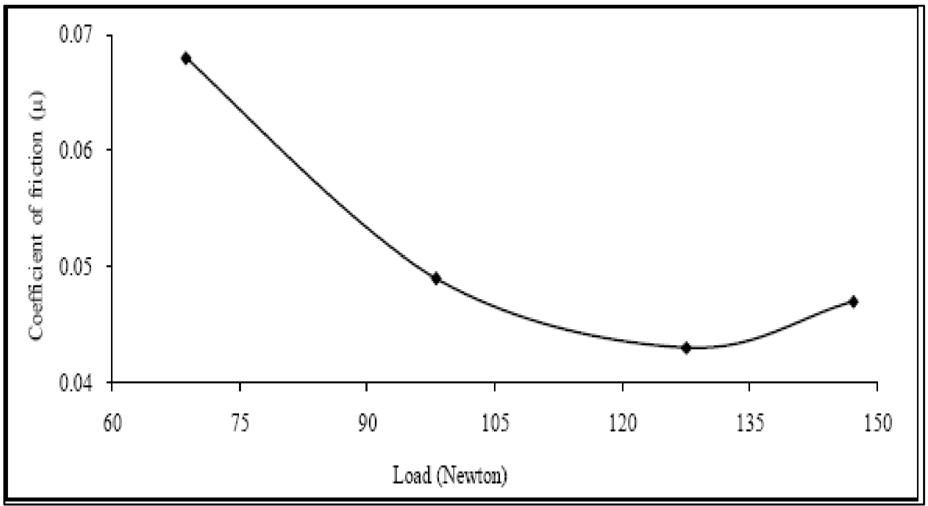


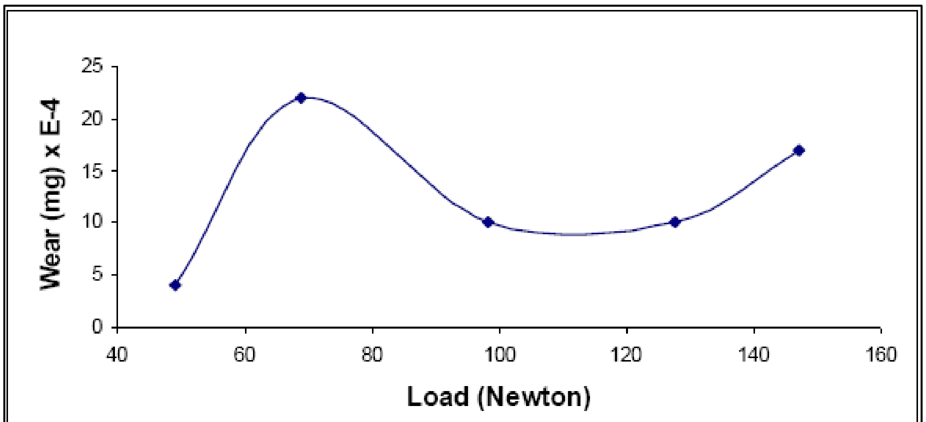
Variation of coefficient of friction with load (Hydrodynamic lubrication at 1000 rpm)

The experiment has been carried out by keeping the speed constant 1000 rpm at 110 mm diameter of disc and varying load.

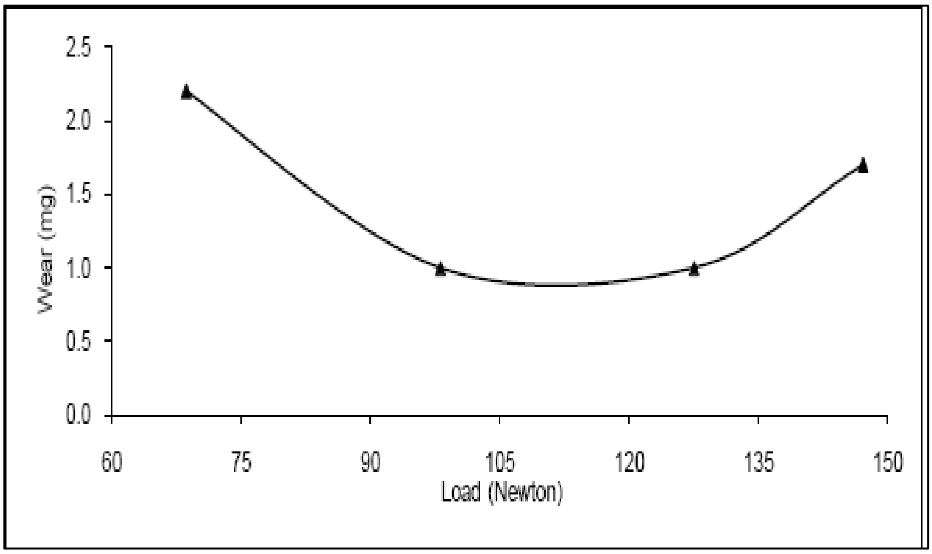
It has been observed that during hydrodynamic lubrication coefficient of friction initially at low load increases but after that continuously decreases if last part would be taken as straight.

Wear characteristic follow the same variation of coefficient of friction with load as shown in fig.





Variation of wear with load
(Hydrodynamic lubrication at 1000 N)



4.0 Summary

Based on the experiments reported in this paper, authors have observed that micro-dimple area density play great role in improving the coefficient of friction at interface in boundary/mixed lubricating conditions. The coefficient of friction first decreases then increases continuously with speed whereas wear remains constant. Whereas in hydrodynamic lubrication coefficient of friction continuously decreases with speed.

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