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Wear Rate Analysis of Hydrodynamic Journal Bearing In Different Conditions

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Abstract: *Friction and wear always occur at machine parts which run together. This affects the efficiency of machines negatively. Hydrodynamic journal bearings are widely used in industry because of their simplicity, efficiency and low cost. Wear due to relative motion between component surfaces is one of the primary modes of failure for many engineered systems. Unfortunately, it is difficult to accurately predict component life due to wear as reported wear rates generally exhibit large scatter. An attempt has been made to study the influence of wear parameters like load, speed, type of lubricant used, temperature, and viscosity of lubricant. The main objective of the study is to evaluate the wear rate of different journalbearing materials (brass and white metal) under similar conditions. The materials are tested in dry and wet lubrication under similar operating conditions. For this purpose we use Pin-on-disc apparatus. It was found that the wear rate of both materials is more in dry conditions compared to lubricated conditions (when tested under similar working conditions). We also found that wear rate of white metal is more as compared to brass and higher frictional force is observed in case of brass material.*

Keywords*: Friction, frictional force, journal bearing, materials, wear rate.*

I. Introduction

Variables in friction and wear testing load, velocity, contact area, surface finish, sliding distance, environment, material of counter face, type of lubricant, hardness of counter face and temperature. Usually, wear is undesirable, because it makes necessary frequent inspection and replacements of parts and also it will lead to deterioration of accuracy of machine parts. It can induce vibrations, fatigue, and consequently failure of parts [1]. Tribology is the art of applying operational analysis to problems of great economic significance, namely, reliability, maintenance, and wear of technical equipments, ranging from spacecraft to household appliances. Surface interactions in a tribological interface are highly complex, and their understanding requires knowledge of various disciplines including physics, chemistry, applied mathematics, solid mechanics, fluid mechanics, thermodynamics, heat transfer, materials science, rheology, lubrication, machine design, performance and reliability [2]. Tribology is crucial to modern machinery which uses sliding and rolling surfaces. Examples of productive friction are brakes, clutches, driving wheels on trains and automobiles, bolts and nuts. Examples of productive wear are writing with a pencil, machining, polishing and shaving. Examples of unproductive friction and wear are internal combustion and aircraft engines, gears, cams, bearings and seals.

In hydrodynamic lubrication, the load supporting high pressure fluid-film is created due to shape and relative motion between the two surfaces. The moving surface pulls the lubricant into a wedge shaped zone, at a velocity sufficiently high to create the high pressure film necessary to separate the two surface against the load [3].

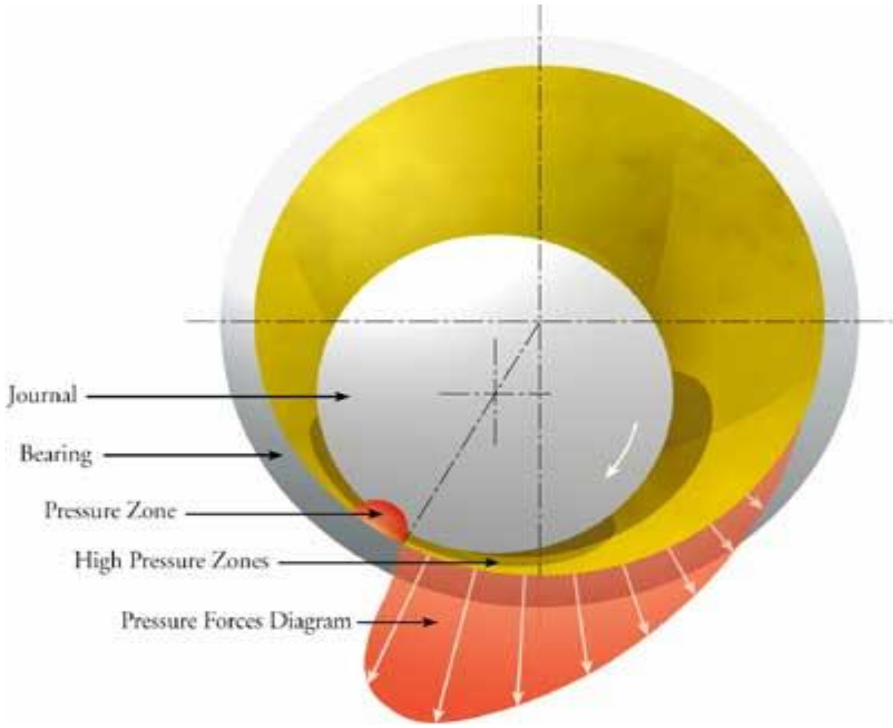

Fig 1: Hydrodynamic journal bearing

Figure shows the principle of working of hydrodynamic journal bearing. Initially when the journal is at rest, it makes contact with the bearing at its lowest point A, due to load 'W'. When the journal starts rotating in anticlockwise direction, it will climb the bearing surface and contact is made at point B. As the speed of the journal is further increased, the lubricant is pulled into the wedge-shaped region and forces the journal to the other side. The converging wedge-shaped film between points C and D supports the journal. Thus in hydrodynamic bearings, it is not necessary to supply the lubricant under pressure [4]. The only requirement is to ensure sufficient and continuous supply of the lubricant.

Wenyi Yan et al [5] has explored that, A computational approach is proposed to predict the sliding wear caused by a loaded spherical pin contacting a rotating disc, a condition typical of the so-called pin-on-disc test widely used in tribological studies. The proposed framework relies on the understanding that, when the pin contacts and slides on the disc, a predominantly plane strain region exists at the centre of the disc wear track. The wear rate in this plane strain region can therefore be determined from a two dimensional idealization of the contact problem, reducing the need for computationally expensive three dimensional contact analyses.

S. Das et al [6] deals with the micropolar lubrication theory to the problem of the steady-state characteristics of hydrodynamic journal bearings considering two types of misalignment, e.g. axial (vertical displacement) and twisting (horizontal displacement). With the help of the steady-state film pressures, the steady-state performance characteristics in terms of load-carrying capacity, misalignment moment and friction parameter of a journal bearing are obtained at various values of eccentricity ratio, degree of misalignment and micropolar fluid characteristic parameters viz. coupling number and non-dimensional characteristic length.

Klaus Friedrich et al [7] have observed during the wear test that , if the particle sizes of the filler material used in PTFE are diminishing down to Nano-scale, significant improvements of the wear resistance of polymers were achieved at very low Nano-filler content (1–3 vol.%). A combinative effect of nanoparticles with short carbon fibers exhibited a clear improvement of the wear resistance of both thermosetting and thermoplastic composites. In addition, this concept allowed the use of these materials under more extreme wear conditions, i.e., higher normal pressures and higher sliding velocities.

H. Unal et al [8] has studied and explored the influence of test speed and load values on the friction and wear behavior of pure Polytetrafluoroethylene (PTFE), glass fiber reinforced (GFR) and bronze and carbon (C) filled PTFE polymers. Friction and wear experiments were run under ambient conditions in a pin-on-disc arrangement. Tests were carried out at sliding speed of 0.32 m/s, 0.64 m/s, 0.96 m/s and 1.28 m/s and under a nominal load of 5 N, 10 N, 20 N and 30 N. From this study the have observed that, PTFE + 17% GFR exhibited best wear performance and is a very good tribo-material between materials used in this study.

According to J. D. Bressana et al [9] the disc wear was more severe as difference in hardness between pin and disc is increased. It can be observed that decrease in pin hardness yields to lower pin wear resistance distance the trends of pin wear rate curves with sliding distance is approximately constant and linear. However, the final stage, some pins are presented the tendency to decrease the wear rate. This is due to the decrease in real contact pressure with increase in the pin contact area and/or increase in hardness of disc track.

Kim Thomsen et al [10] gives a numerical simulation presented for the thermo-hydrodynamic self-lubrication aspect analysis of porous circular journal bearing of finite length with sealed ends. The results showed that the temperature influence on the journal bearings performance is important in some operating cases, and that a progressive reduction in the pressure distribution, in the load capacity and attitude angle is a consequence of the increasing permeability.

Priyanka Tiwari and Veerendra Kumar [11] presents a survey of important papers pertaining to analysis of various types of methods, equations and theories used for the determination of load carrying capacity, minimum oil film thickness, friction loss, and temperature distribution of hydrodynamic journal bearing. Predictions of these parameters are the very important aspects in the design of hydrodynamic journal bearings. The present study mainly focuses on various types of factors which tremendously affect the performance of hydrodynamic journal bearing

Emiliano Mucchi et al [12] proposes an experimental methodology for the analysis of the lubrication regime and wear that occur between vanes and pressure ring in variable displacement vane pumps. The knowledge of the lubrication regime is essential for the improvement of the performance of high pressure vane pumps by reducing wear, increasing the volumetric efficiency and decreasing maintenance costs. Tests using pressure rings of different materials were carried out in order to identify the best material in terms of wear and friction.

Vijay Kumar Dwivedi et al [13] describes a theoretical study concerning static performance of four pocket rectangular recess hybrid journal bearing. Effect of recess length and width variation, number of recess variation on the load bearing capacity and oil flow parameter for rectangular recess has been carried out.

II. Objectives

The nature and consequence of interactions that takes place at interface control its friction, wear, and lubrication behavior. During these interactions, forces are transmitted, mechanical energy is converted, physical and chemical natures including surface topography of interacting materials are altered.

- To find out the behavior of the material from wear and friction point of view and the effect of the various sliding speeds and loads.
- To study the phenomenon of failure of transfer film by making use of pin on disc apparatus.

III. Experimental Setup

In this paper, the hydrodynamic journal bearing materialsbrass and white metal which are widely used in industry are taken. These materials are investigated in order to find the possible consequences of wear and friction under two conditions, i.e. dry and lubricated condition. The diameter and the length of the pins are 10 mm and 30 mm respectively.The wear rate will be relatively small in most of the machinery and engineering tool. For measuring wear, we are using some apparatus and instruments which give results about the wear rate in the tools and machinery.Lubrication are subjected to avoid the excessive wear and friction when there is metal to metal contact present during the relative motion of moving parts in some engineering applications. In designing the wear and friction are the most important factors. Using pin-on-disc tribometer (TR-20LE) readings will be taken.

Fig 2: Pin-On-Disc machine

Specifications of the test rig is given in Table 1.

Table 1: Specifications of pin-on-disk Tribometer (TR-20LE)

Pin size	3 to 12 mm diameter
Length of pin	30mm.
Disc size	165mm diameter x 8mm thick.
Wear track diameter (mean)	50mm to 100mm
Pitch circle diameter	155mm.
Disc rotation speed	100 – 2000 rpm.
Normal load	0 – 200 N.
Friction force output	0 – 200 N digitally recorded
Wear measurement range	0 – 4 microns.
Surface roughness	0.02 microns.
Material of disc	EN8
Hardness of disc material	58 – 62 HRC
Pin material	brass, white metal, copper
Lubricant used	20W40 (HP).

Brass and white metal are taken for this research work. Number of Readings are recorded for the two given conditions. One is dry condition in which no lubricant is used and second is lubricated condition in which a lubricant is used for the given two materials. The materials are tested under two set of speeds one is 800 RPM and other is 1200 RPM. Time span for each set up was different for the two materials and for the two conditions. In this study, frictional force and wear rate of bearing material samples are determined by wearing on Pin on disc wear test rig.

IV. RESULTS AND DISCUSSION

The tests has been done on two different materials and its values are given in Tables. With the help of software and arrangement made in the wear equipment made by Win Ducom. It is possible to record readings at different time spans and for the twoHours test duration 25 readings were recorded for the rate of wear and frictional force.

Different materials which are tested on the machine are given below

(1) Material: BRASS
(a) Condition: Lubricated
(i) Speed: 800 RPM

Testing conditions are given in the table

Table2: testing condition for brass material under lubricated condition

Speed	800 rpm
Linear velocity	2.512 m/sec
Load	1.606 kN
Wear track radius	0.03 m
Pin diameter	10 mm
Testing hours	2 hours
Lubricant used	20W40 (HP)

Observations for brass material under lubricated condition

Sr. No	Displacement (μm)	Frictional Force (N)	Time (min)
1	-4	1	0
5	-4	1.2	20
10	-1	1.4	45
15	0	1.8	70
20	1	1.9	95
25	8	2.3	120

The test result for wear rate for brass material is shown in fig 3

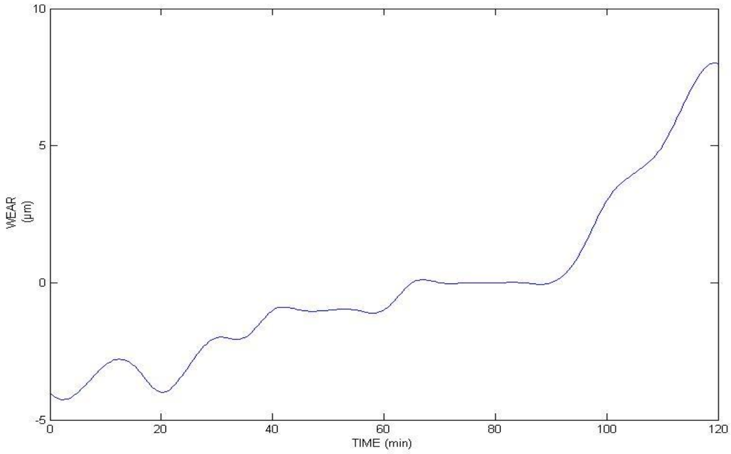

Fig 3: Wear vs Time of Brass 1 (Lubricated)

(ii) Speed: 1200 RPM

Testing conditions are given in the table

Table3: testing condition for brass material under lubricated condition

Testing hours	2 hours
Speed	1200 rpm
Linear velocity	2.512 m/sec
Load	2.606 kN
Wear track radius	0.02 m
Pin diameter	10 mm
lubricant used	20W40 (HP)

Observations for brass material under lubricated condition

Sr. No	Displacement (μm)	Frictional Force (N)	Time (min)
1	-3	1.8	0
5	-4	2.2	20
10	0	2.4	45
15	-1	2.3	70
20	2	3.3	95
25	7	3.1	120

The test result for wear rate for brass material is shown in fig 4

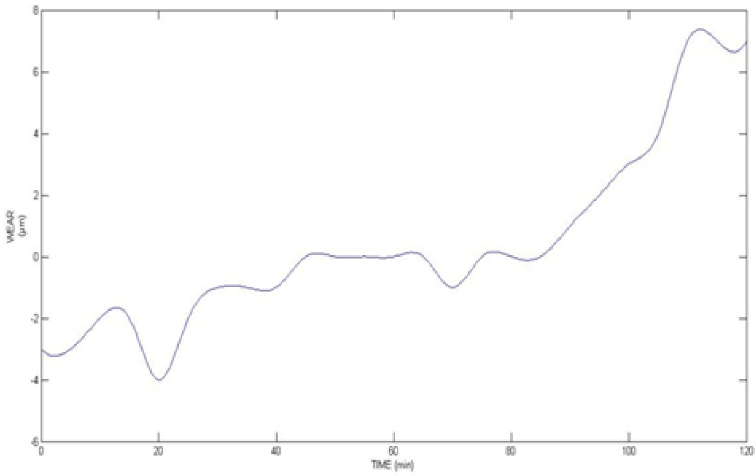

Fig 4: Wear vs Time of Brass 2 (Lubricated)

(b)Condition: Non-Lubricated

(i) Speed: 800 RPM

Testing conditions are given in the table

Table 4: testing condition for brass material under non lubricatedcondition

Testing hours	30 min
Speed	800 rpm
Linear velocity	2.512 m/sec
Wear track radius	0.03 m
Load	1.606 kN
Pin diameter	10 mm

Observations for brass material under non lubricated condition

Sr. No	Displacement (μm)	Frictional Force (N)	Time (min)
1	0	2.8	0
5	0	3.8	8
9	0	4.4	16
12	0	4.6	22
16	2	5.0	30

The test result for wear rate for brass material is shown in fig 5

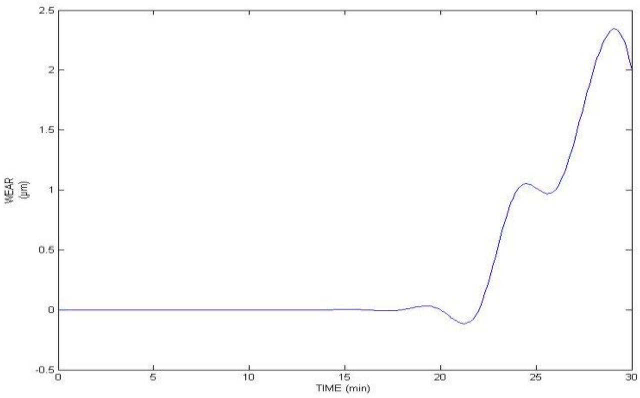

Fig 5: Wear vs Time of Brass 1 (Non-Lubricated)

(ii) Speed: 1200 RPM

Testing conditions are given in the table

Table 5: testing condition for brass material under non lubricated condition

Testing hours	30 min
Speed	1200 rpm
Linear velocity	2.512 m/sec
Load	2.606 kN
Wear track radius	0.02 m
Pin diameter	10 mm

Observations for brass material under non lubricated condition

Sr. No	Displacement (μm)	Frictional Force (N)	Time (min)
1	0	1.6	0
5	0	1.8	8
9	0	1.8	16
13	0	2.0	24
16	1	2.2	30

The test result for wear rate for brass material is shown in fig 6

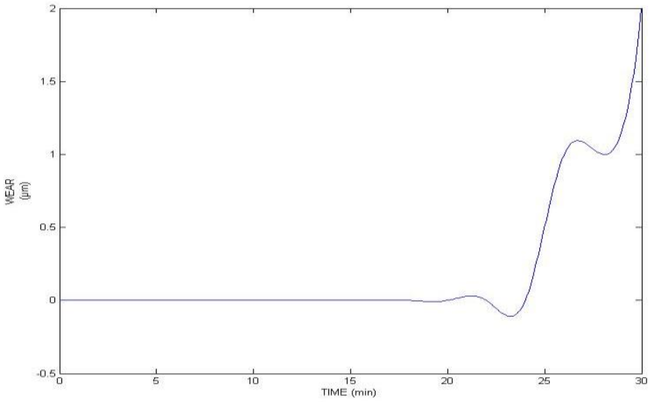

Fig 6: Wear vs Time of Brass 2 (Non-Lubricated)

(II) Material: White Metal
(a)Condition: Lubricated
(i) Speed: 400 RPM

Testing conditions are given in the table

Table 6: testing condition for white metal material under lubricated condition

Testing hours	1 hour 30 min
Speed	400 rpm
Linear velocity	2.512 m/sec
Load	2.606 kN
Wear track radius	0.06 m
Pin diameter	10 mm
Lubricant used	20W40 (HP)

Observations for brass material under lubricated condition

Sr. No	Displacement (μm)	Frictional Force (N)	Time (min)
1	-3	1.4	0
2	-3	1.5	20
3	-1	1.6	40
4	0	2.2	65
5	1	2.3	80
6	3	2.3	90

The test result for wear rate for brass material is shown in fig 7

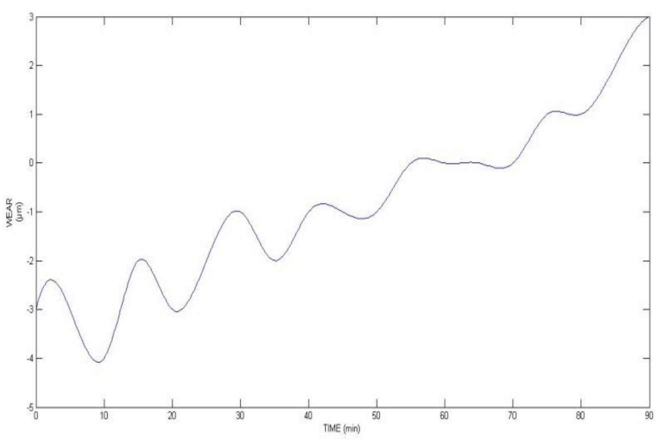

Fig 7: Wear vs Time of White metal 1 (Lubricated)

(ii) Speed: 686 RPM

Testing conditions are given in the table

Table 7: testing condition for white metal material under lubricated condition

Testing hours	1 hour 30 min
Speed	686 rpm
Linear velocity	2.512 m/sec
Load	1.606 kN
Wear track radius	0.035 m
Pin diameter	10 mm
Lubricant used	20W40 (HP)

Observations for white metal material under lubricated condition

Sr. No	Displacement (μm)	Frictional Force (N)	Time (min)
1	-4	1	0
2	-1	1.2	20
3	-1	0.8	40
4	0	0.4	60
5	1	0.2	90

The test result for wear rate for brass material is shown in fig 8

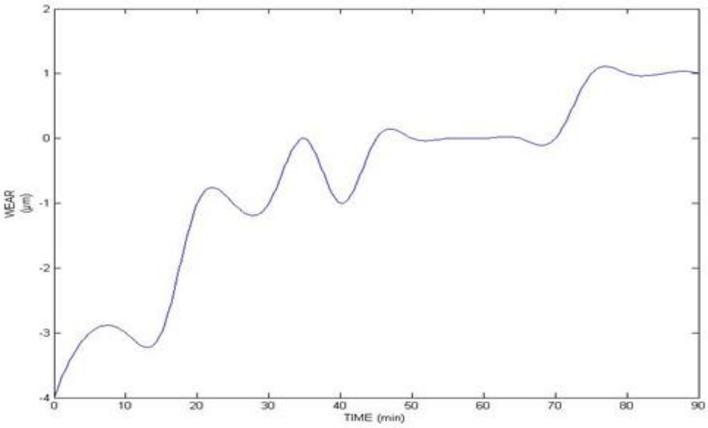

Fig 8: Wear vs Time of White metal 2 (Lubricated)

(b)Condition: Non-Lubricated

(i) Speed: 400 RPM

Testing conditions are given in the table

Table 8: testing condition for white metal material under non lubricated condition

Testing hours	30 min
Speed	400 rpm
Linear velocity	2.512 m/sec
Load	2.606 kN
Wear track radius	0.06 m
Pin diameter	10 mm

Observations for white metal material under non lubricated condition

Sr. No	Displacement (μm)	Frictional Force (N)	Time (min)
1	0	1.8	0
5	0	2.4	8
9	0	2.5	16
13	0	2.7	24
16	2	2.8	30

The test result for wear rate for brass material is shown in fig 9

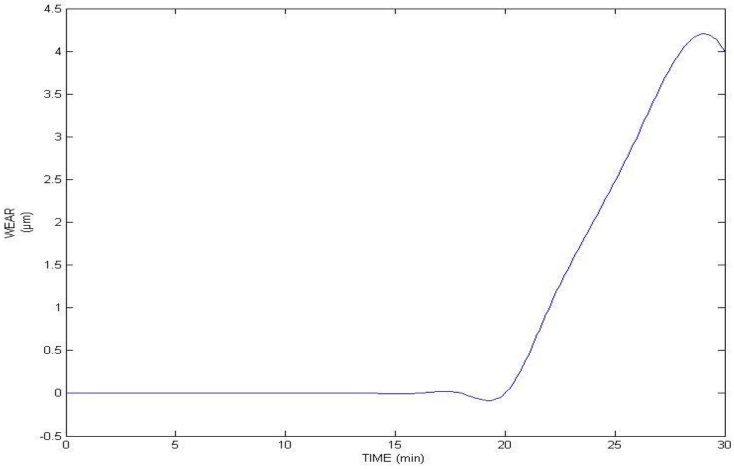

Fig 9: Wear vs Time of White metal 1 (Non-Lubricated)

(ii) Speed: 686 RPM

Testing conditions are given in the table

Table 9: testing condition for white metal material under non lubricated condition

Testing hours	30 min
Speed	686 rpm
Linear velocity	2.512 m/sec
Load	1.606 kN
Wear track radius	0.035 m
Pin diameter	10 mm

Observations for white metal material under non lubricated condition

Sr. No	Displacement (μm)	Frictional Force (N)	Time (min)
1	0	0.7	0
5	0	0.9	8
9	0	1.0	16
13	1	1.4	24
16	2	1.8	30

The test result for wear rate for brass material is shown in fig 10

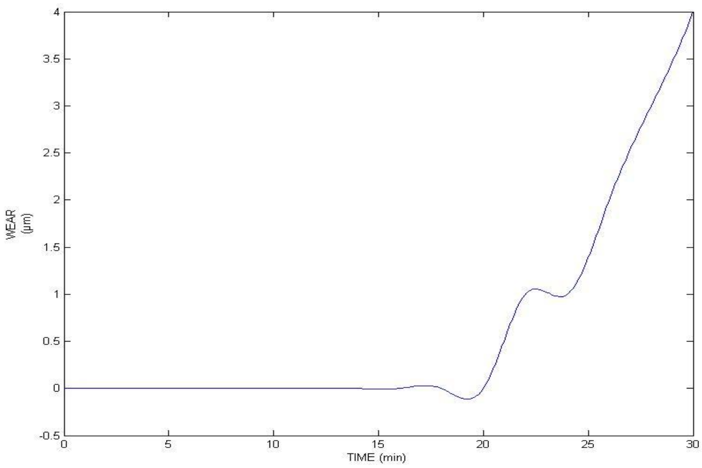

Fig 10: Wear vs Time of White metal 2 (Non-Lubricated)

V. Conclusion & Future Scope

In this paper we study the wear rate of brass and white metal in two different lubrication conditions i.e. lubrication and non-lubrication condition. In this we found that in lubrication condition brass material have shown no wear for first 80 minutes and after that some wear rate is found.In the white metal materialwhen tested in lubrication condition, it is found that abrasive wear takes place between pin and disc and frictional force decreases between them. Wear rate of both materials is more in dry conditions compared to lubricated conditions (when tested under similar working conditions).Wear rate of white metal is more as compared to brass and higher frictional force is observed in case of brass.

The future scope is given below:

1. A theoretical model should be developed for predicting minimum oil film thickness in a dynamic system with radial clearance as a time variant. Such a model would be helpful in developing an expert system for condition monitoring of machines operating in dusty environments.
2. A wider variety of antiwear additives should be tested to characterize for the benefit of industrial users.
3. The bearing operating parameters such as 'K' ratios, bearing clearances, temperature rise, types of contaminants and their concentration need to be varied and their effect on bearing wear and tribological performance be studied in more detail.
4. A study of reduction in friction due to antiwear additives need to be pursued, with regards to energy saving in dusty applications

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