

SCIENCE | ENGINEERING | TECHNOLOGY

e-ISSN: 2319-8753 | p-ISSN: 2347-6710

EDIA

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 9, September 2021

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 7.569

9940 572 462

6381 907 438

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e-ISSN: 2319-8753, p-ISSN: 2347-6710 www.ijirset.com | Impact Factor: 7.569



|| Volume 10, Issue 9, September 2021 ||

DOI:10.15680/IJIRSET.2021.1009014

Analysis of Failure of Transfer Film by Using Pin on Disc Apparatus

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ABSTRACT: Engineers and designers must take care offriction, wear testing load, velocity, contact area, surface finish, sliding distance, environment, the material of counterface, type of lubricant, hardness of counterface, and temperature, etc. while constructing technical equipment. Usually, wear is undesirable, because it makes necessary frequent inspection and replacements of parts and also it will lead to deterioration of the accuracy of machine parts. It can induce vibrations, fatigue, and consequently failure of parts. So, it is important to calculate the wear rate at the design state via developing equipment that can be used for material testing. In this paper, various materials are tested for wear rate by the pin on disc apparatus at lubricated and non-lubricated conditions.

KEYWORDS: Pin on Disc Apparatus, Transfer Film, Tribology, Failure of Transfer Film, Wear Rate Calculations.

I. INTRODUCTION

One of the important objectives of tribology is the regulation of the magnitude of frictional force according to whether we require a minimum or a maximum. This objective can be realized only after a fundamental understanding of the frictional process is obtained for all conditions of temperature, sliding velocity, lubrication, surface finish, and material properties. Tribology is the art of applying operational analysis to problems of great economic significance, namely, reliability, maintenance, and wear of technical equipment, ranging from spacecraft to household appliances. Wear is a progressive loss or removal of material from one or both the surfaces in contact as the result of relative motion between them. Wear is the single most influencing factor which shortens the effective life of a machine or its components. The various factors affecting wear rate are Material of contacting surfaces, Surface finish, Surface hardness, Load, Temperature, Sliding speed, Presence of foreign materials, Environmental condition, Guideways machine tools, etc.

In engineering applications, metal to metal contact often occurs during relative motion rating parts, though lubrication, are subjected to wear and friction as such, their performance characteristics metal to metal are very important from the design point of view. In this paper, the loaded pin is to simulate the parallel surface in motion e.g., Collar bearing, slider in machine tools. It is essential to design a wear rate at the design stage, in doing so, it is essential to develop such equipment which will serve the purpose of material testing.

II. OBJECTIVES

Following are the objectives of this paper:

- **1.** To verify the basic laws of wear.
- **2.** To find out the behavior of the material from the wear and friction point of view and the effect of the various sliding speeds and loads.
- 3. To study the phenomenon of failure of transfer film by making use of pin on disc apparatus.
- 4. To suggest the best suitable material for the journal bearing applications from the tested materials.

III. EXPERIMENTAL SETUP

The TR-20LE pin on disc wear resting is advanced regarding the simplicity and convenience of operation, ease of specimen clamping, and accuracy of measurements, both the wear and frictional force. The machine is designed to apply loads up to 21 kg and is intended both for dry and lubricated test conditions. It facilitates the study of friction.

| e-ISSN: 2319-8753, p-ISSN: 2347-6710| <u>www.ijirset.com</u> | Impact Factor: 7.569| || Volume 10, Issue 9, September 2021 || | DOI:10.15680/IJIRSET.2021.1009014 |



Fig. 1 Pin on Disc Tribometer (TR-20LE)

Wear characteristics are sliding contacts under desired test conditions within machine specifications. Sliding occurs between the stationary pic and the rotating disc. Normal load, rotational speed, and wear track diameter can be varied to suit the test conditions. Tangential frictional force and wear are monitored with electronic sensors and recorded on a PC. These parameters are available as a function of load and speed.

To minimize the vibration during testing, it is fitted with four numbers adjustable anti-vibration pads at the base. Some items like AC motor, variable frequency drive and all electrical items are fitted inside the structure, and sides of it are covered with panels. The wear disc is mounted on the spindle top and is driven by an AC motor through a timing belt, which provides a high torque drive with low vibration. The loading lever with specimen holder fixed at one end and other ends carries a wire rope for suspending dead weights to apply normal load on the specimen. The frictional force produced between specimen pin and disc is directly measured by the load cell at the other end. The specimen pin is placed inside a hardened split jaw and clamped to the specimen holder. To clamp different sizes of specimens, individual jaws are provided for different sizes of pin specimens. The oil for the test is supplied by a lubrication unit fixed at the base of the machine to leak-proof the chamber.

The wear between specimen pin and disc is measured by LVDT and is sensed by a sensor mounted on a lever. The friction between the specimen pin and rotating disc is measured by a strain gauge type load cell mounted on a bracket. The spindle speed is measured by the proximity sensor through an rpm sensor disc. The machine operation is controlled by an electronic controller which is connected to the machine through a set of cables, control cable, and signal input cable. The signals pass from machine to controller and then the controller processed signals to the connected PC. The signals from the wear and frictional force sensor are sent to the instrumentation card, the output from which is sent to the data acquisition card, and the output from it is sent to display on the controller and to PC.

IV. SPECIFICATIONS OF CHARTER

Sr. No.	Name of Component	Specification of Component
1.	Pin size	3 to 12.50 mm diameter.
2.	Length of pin	30mm.
3.	Disc size	165mm diameter x 8mm thick.
4.	Wear track diameter (mean)	50mm to 100mm.
5.	Pitch circle diameter	155mm.
6.	Disc rotation speed	100 – 2100 rpm.
7.	Normal load	0 – 200 N.
8.	Friction force output	0 – 200 N. digitally recorded
9.	Wear measurement range	0-4 microns.
10.	Surface roughness	0.02 microns.
11.	Material of disc	EN8.
12.	The hardness of disc material	58 – 64 HRC.
13.	Pin material	brass, white metal, copper.
14.	Lubricant used	20W40 (HP).

Table 1: Specifications of the Various Components

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|| Volume 10, Issue 9, September 2021 ||

| DOI:10.15680/IJIRSET.2021.1009014 |

V. EXPERIMENTAL RESULTS

BRASS [A] Lubricated condition. Observation No. 1 - Testing hours: 2 hours, Speed: 800 rpm, Linear velocity: 2.512 m/sec, Load: 1.606 kN, Wear track radius: 0.03 m, Pin diameter: 10 mm.

Sr. No	Displacement (µm)	Frictional Force (N)	Time (min)	Sr. No	Displacement (µm)	Frictional Force (N)	Time (min)
1	-4	1	0	14	0	1.8	65
2	-4	1	5	15	0	1.8	70
3	-3	1.2	10	16	0	1.8	75
4	-3	1.2	15	17	0	1.8	80
5	-4	1.2	20	18	0	1.8	85
6	-3	1.3	25	19	0	1.9	90
7	-2	1.3	30	20	1	1.9	95
8	-2	1.4	35	21	3	2.2	100
9	-1	1.6	40	22	4	2.3	105
10	-1	1.4	45	23	5	2.3	110
11	-1	1.5	50	24	7	2.3	115
12	-1	1.5	55	25	8	2.3	120
13	-1	1.7	60				

Table 2: Observation Table



Graph : 1 (a) Frictional Force vs Time. (b) Wear vs Time

Observations No. 2, 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

Sr. No	Displacement (µm)	Frictional Force (N)	Time (min)	Sr. No	Displacement (µm)	Frictional Force (N)	Time (min)
1	-3	1.8	0	14	0	2.9	65
2	-3	1.9	5	15	-1	2.3	70
3	-2	2	10	16	0	2.6	75
4	-2	2.1	15	17	0	2.7	80
5	-4	2.2	20	18	0	2.7	85
6	-2	2.3	25	19	1	3.2	90
7	-1	2.3	30	20	2	3.3	95
8	-1	2.3	35	21	3	3.7	100
9	-1	2.2	40	22	4	3.2	105
10	0	2.4	45	23	7	3.1	110
11	0	2	50	24	7	3.1	115
12	0	2.6	55	25	7	3.1	120
13	0	2.7	60				

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Table 3: Observation Table

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Volume 10, Issue 9, September 2021

| DOI:10.15680/IJIRSET.2021.1009014 |



Graph :2 (a) Wear vs Time. (b) Frictional Force vs Time

[B] Non-Lubricated Condition, Observations No. 3, Testing hours: 30 min, Speed: 800 rpm, Linear velocity: 2.512 m/sec, Load: 1.606 kN, Wear track radius: 0.03 m, Pin diameter: 10 mm

Table 4: Observation Table

Sr.	Displacement	Frictional	Time
No	(µm)	Force (N)	(min)
1	0	2.8	0
2	0	3.3	2
3	0	3.2	4
4	0	3.4	6
5	0	3.8	8
6	0	4.0	10
7	0	4.2	12
8	0	4.3	14
9	0	4.4	16
10	0	4.4	18
11	0	4.4	20
12	0	4.6	22
13	1	4.8	24
14	1	4.8	26
15	2	4.8	28
16	2	5.0	30





(b)

Graph :3 (a) Wear vs Time. (b) Frictional Force vs Time

International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET)

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Volume 10, Issue 9, September 2021

|DOI:10.15680/IJIRSET.2021.1009014|

Observations No. 4, 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

Table 5: Observation Table

Sr.	Displacement	Frictional	Time
No	(µm)	Force (N)	(min)
1	0	1.6	0
2	0	1.6	2
3	0	1.7	4
4	0	1.7	6
5	0	1.8	8
6	0	1.8	10
7	0	1.8	12
8	0	1.8	14
9	0	1.8	16
10	0	1.8	18
11	0	1.9	20
12	0	1.9	22
13	0	2.0	24
14	0	2.0	26
15	1	2.1	28
16	1	2.2	30



(b) Graph :4 (a) Frictional Force vs Time. (b) Wear vs Time

White Metal

[A] Lubricated condition, Observation No. 1, 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

Table	6:	Observation	Table
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Sr. No	Displacement (µm)	Frictional Force (N)	Time (min)	Sr. No	Displacement (µm)	Frictional Force (N)	Time (min)
1	-3	1.4	0	11	-1	1.7	50
2	-3	1.4	5	12	0	1.9	55
3	-4	1.4	10	13	0	2	60
4	-2	1.5	15	14	0	2.2	65
5	-3	1.5	20	15	0	2.2	70
6	-2	1.6	25	16	1	2.3	75
7	-1	1.5	30	17	1	2.3	80
8	-2	1.5	35	18	2	2.3	85
9	-1	1.6	40	19	3	2.3	90
10	-1	1.7	45				

e-ISSN: 2319-8753, p-ISSN: 2347-6710 www.ijirset.com | Impact Factor: 7.569



|| Volume 10, Issue 9, September 2021 ||

| DOI:10.15680/IJIRSET.2021.1009014 |



Graph :5 (a) Frictional Force vs Time. (b) Wear vs Time

Observation No. 2,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

Table 7: Observation Table

Sr. No	Displacemen	Frictional	Time
	t (µm)	Force (N)	(min)
1	-4	1	0
2	-3	0.9	5
3	-3	1	10
4	-3	1.2	15
5	-1	1.2	20
6	-1	1.3	25
7	-1	1.3	30
8	0	1.3	35
9	-1	0.8	40
10	0	0.6	45
11	0	0.7	50
12	0	0.5	55
13	0	0.4	60
14	0	0.6	65
15	1	0.3	70
16	0	0.2	75
17	1	0.3	80
18	0	0.2	85
19	1	0.2	90







Graph :6 (a) Wear vs Time. (b) Frictional Force vs Time

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Volume 10, Issue 9, September 2021

| DOI:10.15680/IJIRSET.2021.1009014 |

[B] Non-Lubricated condition, Observation No. 3,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

Table 8: Observation Table

			-
Sr.	Displacement	Frictional	Time
No	(µm)	Force (N)	(min)
1	0	1.8	0
2	0	2.4	2
3	0	2.4	4
4	0	2.4	6
5	0	2.4	8
6	0	2.4	10
7	0	2.5	12
8	0	2.5	14
9	0	2.5	16
10	0	2.6	18
11	0	2.6	20
12	0	2.7	22
13	0	2.7	24
14	1	2.8	26
15	1	2.8	28
16	2	2.8	30



(b) Graph : 7 (a) Wear vs Time (b) Frictional Force vs Time

Observation no. 4, 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.

Table 9: Observation Table

Sr.	Displacement	Frictional	Time
No	(µm)	Force (N)	(min)
1	0	0.7	0
2	0	0.8	2
3	0	0.8	4
4	0	0.8	6
5	0	0.9	8
6	0	0.9	10
7	0	1.0	12
8	0	1.0	14
9	0	1.0	16
10	0	1.2	18
11	0	1.2	20
12	0	1.4	22
13	1	1.4	24
14	1	1.6	26
15	1	1.6	28
16	2	1.8	30



Graph :8 (a) Frictional Force vs Time. (b) Wear vs Time



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|| Volume 10, Issue 9, September 2021 ||

| DOI:10.15680/IJIRSET.2021.1009014 |

VI. CONCLUSION

[A] For Lubricated Conditions

The wear rate of bearing material depends on the temperature. During the first test (brass in lubricated condition), initially, the air conditioner was on for 81 minutes. There are no visible wear takes place, but afterward, when we stop the air conditioner from the 94^{th} minute the visible wear takes place. As frictional force increases, the wear of material also increases. The wear rate of material depends on material hardness. As we tested two specimens (Brass – 90HB and White metal – 40HB) under similar conditions, the material having less hardness or softer material wear is more. Temperature and contamination of abrasives in lubricants affect the performance of lubricants. During the fourth test (white metal in lubricated condition), the formation of bubble/foaming of lubricant takes place in an oil tank. Due to this, the abrasive particles which settle down in a tank get mixed with oil. This changed oil is very sticky and forms a layer between pin and disc, therefore, the frictional force between the pin and disc decreases. And wear that takes place is abrasive wear. As the abrasives trapped between pin and disc

[B] For Non-Lubricated Conditions

Comparison of wear: The wear rate of both materials is more in dry conditions compared to lubricated conditions (when tested under similar working conditions). The wear rate of white metal is more as compared to brass. The higher frictional force is observed in the case of brass.

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Impact Factor: 7.569





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