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"TO STUDY WEAR AND FRICTION AT CONTACT SURFACE OF CAM AND FOLLOWER OF I.C. ENGINE"

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ABSTRACT - *As we normally noticed in the IC engine that due to friction between cam & follower, it decreases efficiency and also increases the resistance between contact surface of cam & follower and also there is an issue of wear between surface and due to that the surface of cam reduces and gets damages by cracks. So we are trying to analyze the wear & friction between surfaces of cam & follower and after that trying to decrease the same with the help of applying coating of material on surface of cam which will help for reducing wear & thereof lubrication between surfaces of cam & follower in IC engine. For that first of all we have to analyze the working & materials of cam & follower and IC engine.*

Keywords – Cam, Follower, friction, Wear, coating material, lubricant.

1. INTRODUCTION

IC ENGINE

IC engine is the engine where heat generation takes place inside cylinder. An internal combustion engine is a heat engine where chemical energy is converted into mechanical energy with the help of different components. The components used in IC engines are:-

- Cylinder
- Cylinder head
- Spark plug
- Fuel injector
- Piston
- rocker arm
- Valve & Valve Mechanism
- Connecting rod
- Camshaft

Cam:

Cam can be a rotating piece or sliding piece linkage mechanism used for transforming rotary into translating motion.

Types of CAM

- Plate cam
- Cylindrical cam
- Snail cam
- Linear cam

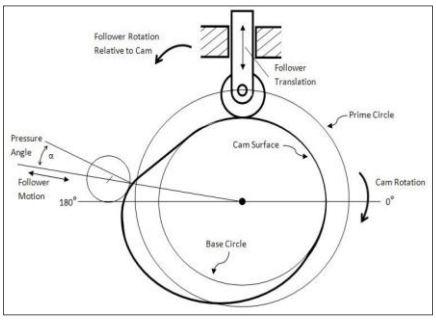


Fig-1.1: Working of cam and follower

Camshaft:

Cam shaft is a shaft of which a cam forms an integral part. In general language camshaft is a shaft constructed to joint & use number of cam as a motion.

Material used in camshaft are billet steel, cast iron, mild steel, stainless steel. The relation between the rotation of camshaft & the rotation of crankshaft has critical importance. The camshaft is used to operate valves. The cam lobes forces valve to open by pressing on the same.

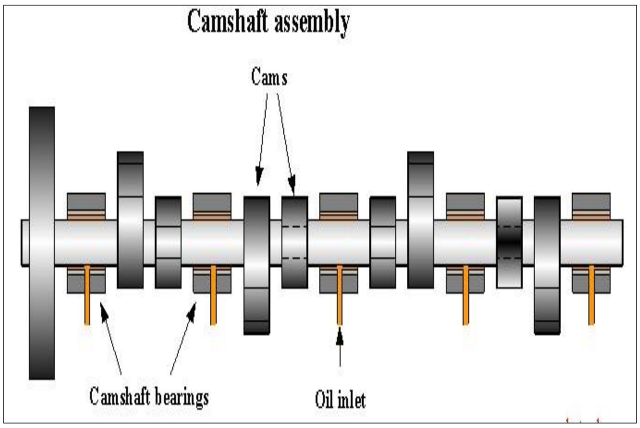


Fig-1.2: Camshaft Assembly

Follower:

Follower is used to transfer rotary motion to rocker arm mechanism which converts into leverage motion.

Types of follower:

- Knife edge follower: in this type of follower there is point contact between cam & follower. So, this is not used for having high rate of wear.
- Roller follower: in roller follower, the roller is fit at the end of follower, so the contact between cam & follower is smooth & wear is less. Use of this follower is limited because there is pin joint which brake at high speed.
- Flat or mushroom follower: the advantage of this follower is side thrust only produced due to friction between cam & follower.
- Flat faced follower: this is modification of mushroom follower .it is used where space is less.

We are finding wear on surface between cam & follower so after that we will get accurate amount of wear. So we have used material like carbon nitrate, silicon nitrate, manganese phosphate, chromium etc. to reduce wear. We have studied different references related to project so we have come to know that what progress is already done on the project & which technique we can use for solution, we have also come to know about different new issues related to project. So we have performed many experiment in different rpm with different materials. We have also find friction force and wear with use of mathematical formula and also with the help of pin on disc machine. Then we have compare the reading and wear graph of standard material and coating material and selected the best material out of it. We have selected manganese phosphate as best material which will reduce wear and friction force. To reduce the friction to the greater extend we have used 20W 40 engine oil with ZDDP.

2. Design: Analysis, Design Methodology and Implementation Strategy

h= 00.0254m

$\beta = 100°$

N = 900 rpm

Spring constant $k = \dfrac{F}{x}$

where, x = spring displacement = 0.040 m

Max. Power at 5000 rpm = 34.7 ps = 25.9 kW

Max. Power at 900 rpm = $\frac{900\times 25.9}{5000}$

= 4.662 kW =4662 Nm/s

Linear velocity = v $= r\times RPM\times 0.10472$

$= 64\times 900\times 0.10472$

∴ v = 6.031872 m/s

$F=\frac{P}{v}=\frac{4662}{6.031872}$ = 772.9 N ≅ 773 N

Spring constant = $k=\frac{F}{x}=\frac{773}{0.040}$ = 19345.95 N/m

W= 0.90 kg = 8.896 N

d = 0.0157 m

l_2 = 0.074 m

l_1 = 0.00785 m

R_{max} = 0.024 m

μ = 0.05;

Assuming rotation of cam is 75°

Eq. of cycloidal motion are:

Displacement = $y=h\left[\frac{t}{T}-\frac{1}{2\pi}\sin\left(2\pi\frac{t}{T}\right)\right]$

Velocity = $v=y'=\frac{h}{T}\left[1-\cos\left(2\pi\frac{t}{T}\right)\right]$

Acceleration = $a=y''=\frac{2\pi h}{T^2}\sin\left(2\pi\frac{t}{T}\right)$

Where T= $\frac{60}{N}\cdot\frac{P}{360}=\frac{60}{900}\cdot\frac{100}{360}=1/54$ sec.

Displacement

$$y_{75}=0.0254\left[\frac{75}{100}-\frac{1}{2\pi}\sin\left(2\pi\frac{75}{100}\right)\right]$$

$y_{75}=0.0230$ m/s

Velocity = $y'_{75}=\frac{0.0254}{1/54}\left[1-\cos\left(2\pi\frac{75}{100}\right)\right]$

$y'_{75}=1.3716$ m/s

Acceleration = $y''_{75}=\frac{2\pi\times 0.0254}{\left(1/54\right)^2}\sin\left(2\pi\frac{75}{100}\right)$

$y''_{75}=-464.82$ m/s

Acceleration y'' is negative, the inertia force due to this acceleration is actually decreasing f_n; the inertia force is:

$\frac{W}{g}y''=\frac{8.896}{9.81}\times 464.82=421.51N$ (upward),

$F_s=k(0.009+y)$

$=19345.95(0.009+0.023)$

$F_s=619.007N$ (Downward)

$P=F_s-\frac{W}{g}y''$

$=619.007-421.51$

P=197.56 N

To study wear & friction at contact surface of cam & follower in IC engine

Normal force acting on follower,

$$F_n = \frac{P}{\cos\alpha - \left(2\mu\frac{l_1}{l_2} + \mu - \frac{\mu^2 d}{l_2}\right)\sin\alpha}$$

$$F_n = \frac{197.56}{\cos 10 - \left(2(0.05)\frac{0.00785}{0.074} + 0.05 - \frac{0.05^2(0.0157)}{0.074}\right)\sin 10}$$

$F_n = 202.75$ N

The torque acting on a cam from a radial translating flat follower,

$$T_0 = F_n \frac{y'}{W}\cos\alpha$$

$$T_0 = 202.75 \times \frac{1.3716(60)}{900(2\pi)}\cos 10$$

$T_0 = 2.905$ Nm

Friction force, $F_f = \mu_r \times F_n$

$F_f = 0.05 \times 202.75$

$F_f = 10.1375$ N

Linear wear being a linear decrement of the specimen:

$$\frac{Z}{l} = a_0\left(\frac{P_0}{H_1}\right)^{a_1}\left(\frac{H_2}{H_1}\right)^{a_2}\mu^{a_1}$$

$$\frac{Z}{0.07} = 1.13\cdot 10^{-5}\left(\frac{255.3\cdot 10^6}{450}\right)^{1.00}\left(\frac{370}{450}\right)^{2.69} 0.05^{3.23}$$

Z = 14.68 µm

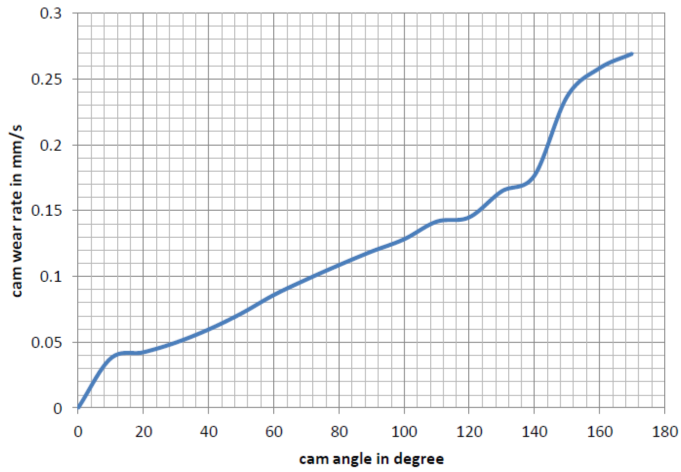


Fig-2.1: Cam wear Vs. Cam Angle

Table-2.1: Wear Model Coefficient

Coefficient a_i	Average Value	Standard Deviation
ln a_0	-11.39	0.36
a_0	$1.13\cdot 10^{-5}$	-
a_1	1.00	0.11
a_2	2.69	0.42
a_3	3.23	0.13
R^2	0.8	-

Specifications:

SPECIFICATION OF MACRO PIN ON DISK (rotary tribometer) by ducom:

Table-2.2: Technical Specifications

Technical specifications				
Parameter	Units	Min	Max	Remarks
Pin / ball diameter	Mm	3	12	Sample holder of 3,6,10 &12mm
Disc diameter	mm		165	Thickness up to 8mm
Disc rotation speed	Rpm	200	2000	1rpm least count
Normal load	N	0	200	In steps of 5N
Frictional force	N	0	200	1N Least count
Wear measurement range	µm	0	1200	µm Least count
Wear track radius	mm	50	145	
Present timer	Hr/min/sec	99/59/99		

Fig-2.2: The Ducom Macro PoD

Description:

The Ducom Macro PoD comprises of a rotary drive which controls disc rotation. The counter specimen - which may be a ball, pin or any other custom geometry - is held firmly in a friction/loading arm. A known load is applied upon the counter specimen to achieve the desired contact stress.

The Macro PoD is a fully computer controlled test system. Operator may choose and set the desired test parameters from the Ducom TriboAcquire control and data acquisition system. The test parameters are displayed and output is recorded.

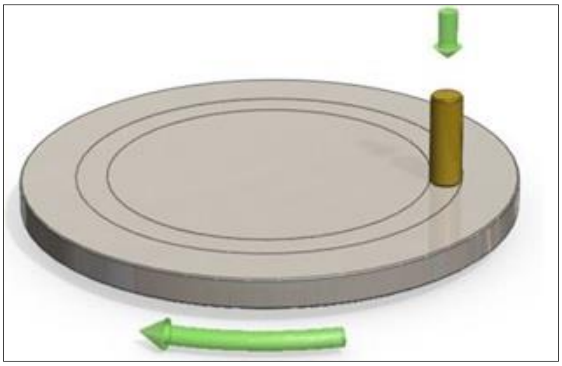


Fig-2.3: Working of The Ducom Macro PoD

Properties of ZDDP

CERTIFICATE OF ANALYSIS

Product Code	:	NC 4575
Market Name	:	ANTIOXIDANT ZDDP NC 4575
Manufacturer	:	SERIX SPECIALITIES
Manufacturing Point	:	GUJARAT. INDIA
Batch No	:	/ 16 / T (Standard Specification)

Fig-2.4: Properties of ZDDP

TEST	PROCEDURE	MIN	MAX	VALUE
Specific Gravity @ 15.6° C	ASTM D 1298	1.08	1.18	
Viscosity @ 100° C., cst	ASTM D 445	8.0	18.0	
Color, ASTM Dilute	ASTM D 1500	1.0	3.0	
% Water	ASTM D 95		0.2	
phosphorus	GL-PH-1B	8.2	9.9	
sulfur	GL-SU-6/10	16	21	
Zinc	GL-EDTA-1	9.5	11.0	
Flash point, ° C., PMCC	ASTM D 93	121		

Fig-2.5: Properties of ZDDP

Table-2.3: Properties of Testing Material

Properties Of Testing Materials		
	Disc Material	**Pin Material**
Type	Grey cast iron	Chilled cast
C%	3.1 - 3.3	3.6
Si%	2.1 - 2.4	2.3
Mn%	0.7 - 0.9	0.6 - 1.2
P%	0.2	0.12
S%	0.1	0.30
Cr%	1.0 - 1.25	0.15
Mo%	0.4 - 0.7	-
Ni%	0.4	0.50

Properties of Lubricant

Autorun 20W40 (by Sesha lubricants)

Table-2.4: Properties of Lubricant

Kinematic Viscosity cSt @ 100.C	13.5-15.5
Viscosity Index, Min.	110
Flash Point (COC), .C Min.	200
Pour Point, ˚C Max.	[-]6
TBN mg koh/gm	9.5-12.5
Kinematic Viscosity cSt 100˚C	13.5-15.5
Viscosity Index,Min.	110
Flash Point (COC), .C Min.	200
Pour Point, .C Max.	[-]6
TBN mg koh/gm	9.5-12.5

Auto Run Multi Grade Engine Oil Equivalents to IS 13656-2002 can meet API SC/CC requirements of petrol and diesel Engines also the unique additives of Auto Run oil ensure High viscosity index that improves maximum power and trouble free engine. It is recommended for use in all models of L.M.V.&H.M.V.

WORKING METHODOLOGY

Fig-2.6: MACRO PIN ON DISK (rotary tribometer) by ducom:

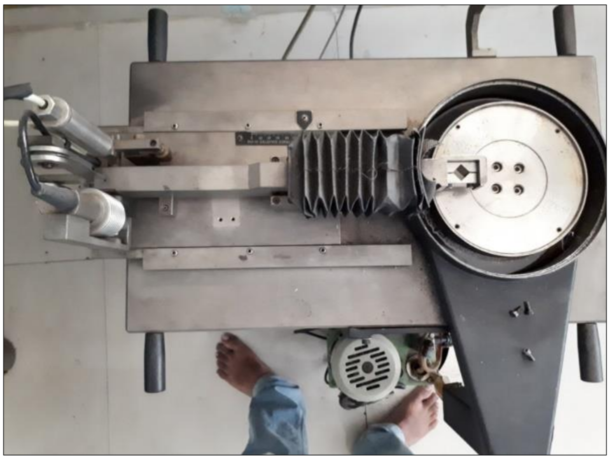


Fig-2.7: MACRO PIN ON DISK (rotary tribometer) by ducom:

Sensors & Drive unit:

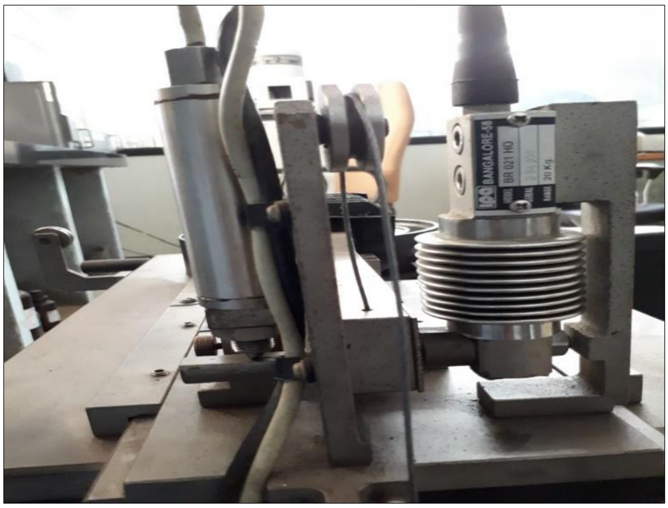


Fig-2.8: Sensors & drive units

Fig-2.9: Sensors & Drive units

Test piece preparation:

Plate:

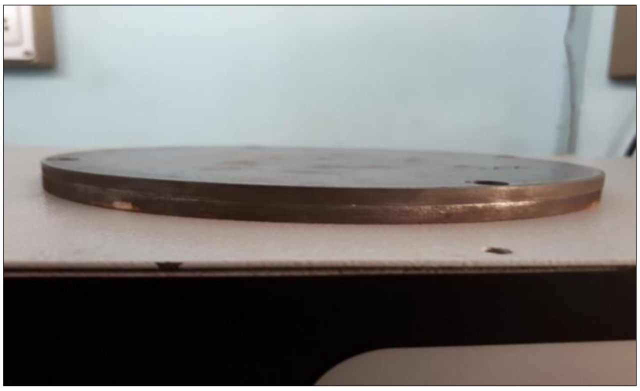


Fig-2.10: Plate

Fig-2.11: Plate

Pin:

Fig-2.12: Pin

Fig-2.13: Pin

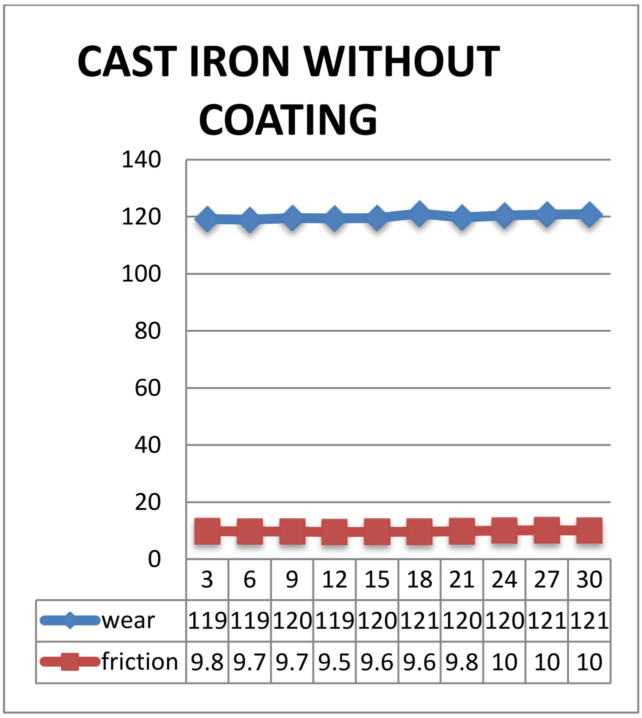
3. Implementation:

A) Standardized plate : Cast iron:

Fig-2.14: Before

Fig-2.15: After

- At 900 rpm & 120 mm wear track diameter :



	3	6	9	12	15	18	21	24	27	30
wear	119	119	120	119	120	121	120	120	121	121
friction	9.8	9.7	9.7	9.5	9.6	9.6	9.8	10	10	10

Fig-2.16: wear track diameter at different speeds

B) Standardized material(cast iron) with coating of chromium:

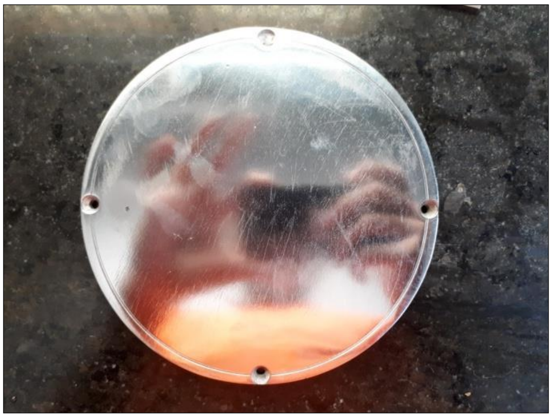


Fig-2.17: Before

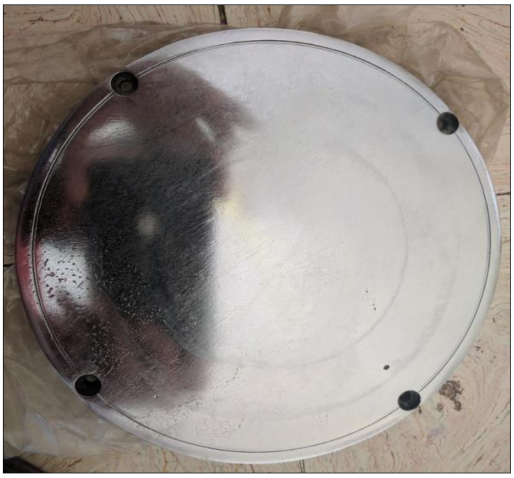


Fig-2.18: After

At 900 rpm & 120 mm wear track diameter:

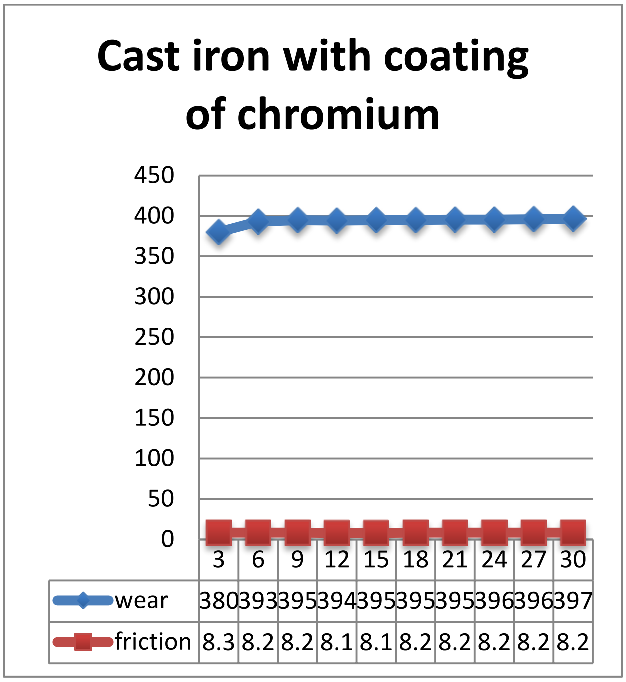


Fig-2.19: wear track diameter at different speeds

Fig-2.21: Before

- At 1200 rpm & 80 mm wear track diameter:

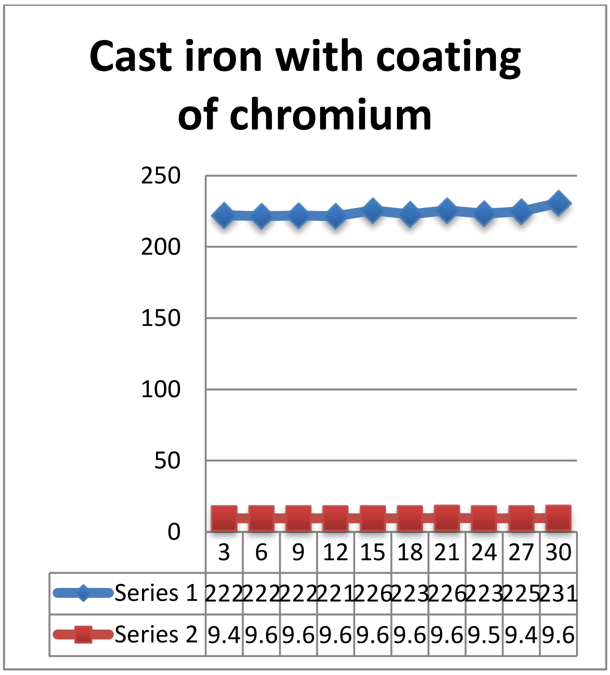
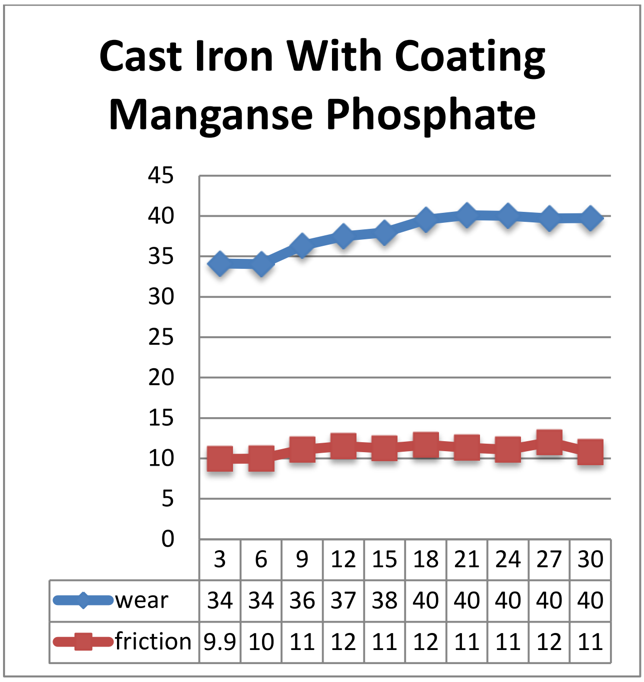


Fig-2.20: wear track diameter at different speeds

Fig-2.22: After

- At 900 rpm & 120 mm wear track diameter:

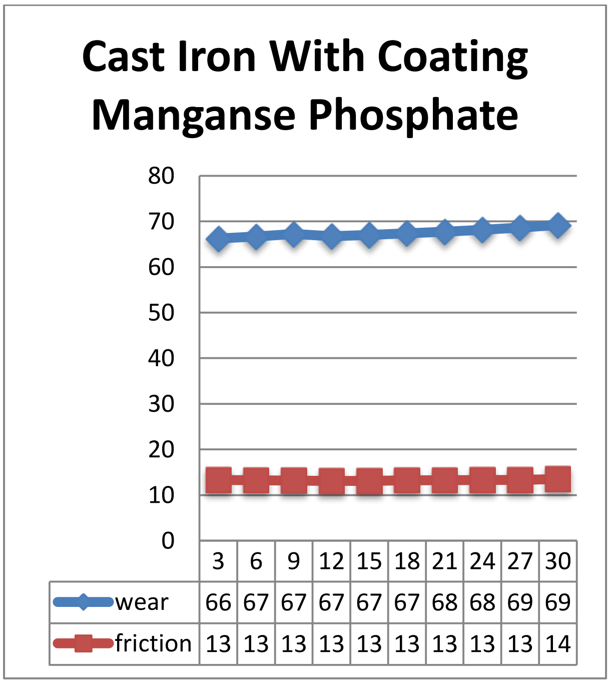
C) Standardized material(cast iron) with coating of Manganese phosphate:



	3	6	9	12	15	18	21	24	27	30
wear	34	34	36	37	38	40	40	40	40	40
friction	9.9	10	11	12	11	12	11	11	12	11

Fig-2.23: wear track diameter at different speeds

At 1200 rpm & 80 mm wear track diameter:



	3	6	9	12	15	18	21	24	27	30
wear	66	67	67	67	67	67	68	68	69	69
friction	13	13	13	13	13	13	13	13	13	14

Fig-2.24: wear track diameter at different speeds

4. Summary of Results:

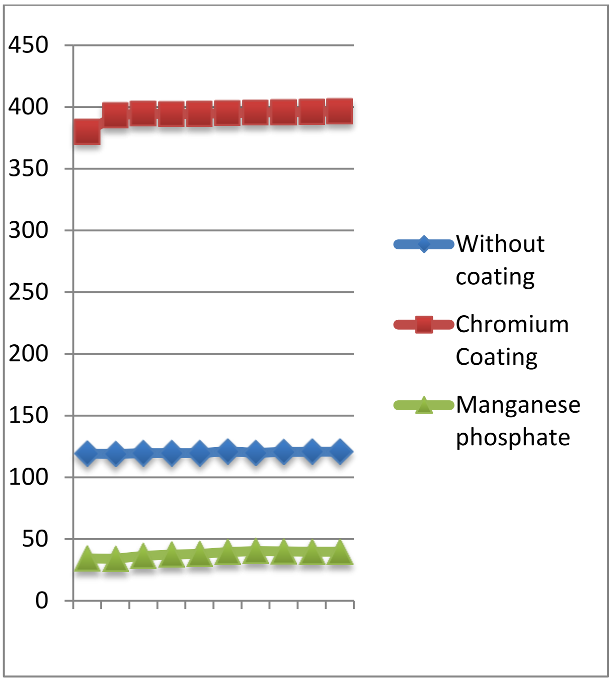


Fig-2.25: Summary

We've found many research papers for our topic and then we started analyzing every research paper one by one. After study on research papers we got idea that which materials are used for cam-follower. We also found out the procedure for measuring torque, spring force, wear and friction. Then we have selected many materials for coating like silicon nitrate, manganese phosphate, Diamond like Coating (DLC), titanium carbide, chromium, etc. but materials like silicon nitrate, DLC, titanium carbide are not economical for the use as their cost is very high, so we have selected manganese phosphate and chromium as a material for coating on cast iron disc. For reduction of friction to greater extent we have used 20W40 engine oil with ZDDP additive which also helps in anti-scuffing.

Unique features Of Our Work:

Expected advantages are:

- Reduction In Wear
- Increased Surface Finish
- Reduced Scuffing
- Proper Lubrication

4. Conclusion:

we have selected many materials such as silicon nitrate, manganese phosphate, Diamond like coating (DLC), titanium carbide, chromium, etc. from the analysis of different material we have found that manganese phosphate and chromium are good for coating. After performing the experiment of coating of manganese and chromium on cast iron at different rpm we have concluded that manganese phosphate is more effective in reduction of wear and it is also economical and easily available in market and we have also used lubricating oil 20W40 engine with ZDDP as an additive which reduce the friction to greater extent.

5. Acknowledgements

We express our sincere gratitude to our guide Asst. Prof. Gautam Vardhe and also to Asst. Prof. Jay Patel, and Asst. Prof. Hirak Patel. We also thank to Dr. B. M. Sutariya for the technical support which made this project possible. This could not have been possible without the participation and assistance of so many people whose names may not be all enumerated. Their constant suggestion and ideas have been invaluable to our work and their thoroughness and work ethic are laudable and worthy of emulation. Also for this project work information has been collected from various sources such as textbooks, research papers, journals, articles and patents, so we also express our gratitude to their authors and publishers for their valuable material.

6. Scope of Future Work:

- Design Of Cam
- Design Of Follower
- Different Type Of Lubricant

7. REFERENCE:

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