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Development of Ball Point Type Follower with Single Ball Groove Type Cam

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ABSTRACT

Generally in an automobile, as a cam and follower, camshaft and valve are used. The valve and the cam come in contact with a flat surface. Because of this flat surface contact friction and wearing takes place. There are different types of followers like a knife edge, roller, flat type followers, but in all these types more friction and wearing takes place. So in concern to this friction and wearing issue, Single groove cam with ball point type follower design is presented. In this design of follower lubrication of follower will be there continuously and due to that heat generation, friction, wearing will be lesser comparatively from other followers. In this ball type follower, a ball pen kind of mechanism would be there. As a result wearing and friction will be lesser on cam and cam grooves comparatively to a flat surface.

Keyword: Ball Point Type Follower, Single Groove Cam, Cam and Follower, Single Groove Cam and Ball Point Type Follower.

1. INTRODUCTION

As we normally noticed in the IC engine that due to friction between cam & follower, it decreases efficiency & also increases the resistance between the contact surface of cam & follower & also there is an issue of wear between surface & due to that the surface of cam reduces & gets damaged by cracks. So we are trying to analyze the wear & friction between surfaces of cam & follower & after that trying to decrease the same with the help of applying a coating of material on the surface of the cam which will help for reducing wear & thereof lubrication between surfaces of cam & follower in IC engine. S.M. Muzakkir (2015) have an investigation in the internal combustion engine, the push rod type cam & follower mechanisms have high friction losses. In this research work, it tried to minimize the friction losses of push rod type valve system. Friction losses are the main reason for high cost of the mechanical system. The amount of energy lost during operation depends on friction, which is very important. Reducing this friction may can decrease the energy loss if friction is less, then wear of the components will decrease. It requires considering tribological to minimize friction. This paper presents a reduction of friction of push rod type valve system. [1] J. Michalski, J. Marszalek and K. Kubiak (1999) have investigated quantify wear mechanism of a direct valve-gear. Normally camshafts are made of nodular cast iron, surface hardened steel. These experiments have taken place in a laboratory equipped with an engine head having camshaft, followers, etc. And it was also creating necessary condition for a required run of the valve gear. Wear of cam can be defined by comparing lifts of cams. Coordinative measuring machines & a perpendicular optimizer were used for measuring height. Considering kinematics of combustion engine, we can assume that value of hertz man pressure makes an effect on pitting wear value. Normally there is increased wear between cam & follower due to the propagation of cracks.[2] T.S Eyer & B. Crawley In IC engine most loaded mating part are cam and follower. Many research shows that cam nose often operates in boundary lubrication regime, surrounding face quality, lubrication metallurgy. Recently the problem has been an encounter with overhead camshaft finger follower & use of hard chromium plating on the same component has presented a problem which is similar to piston ring where it has been found that it is difficult to lubricate on smooth chromium. There has been developed a commercial process for the success of production on surface porosity to enhance retention& supply of lubricant .the care should be taken that it does not contribute to breakdown of chromium plate when clearance increase in cam & follower the wear will increase, engine performance deteriorate & noise level increase. Scuffing occur in early running there is rapid deterioration which results from metal transfer & rough surface topography [3]

1.1 Cam

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

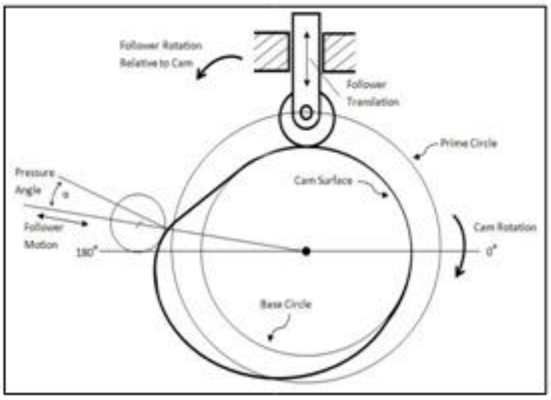

Fig 1: Cam and Follower Mechanism

Types of Cam:

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

Camshaft

Cam shaft is a shaft of which a cam forms an integral part. In general language, camshaft is a shaft constructed to joint & uses number of the cam as a motion. The material used in camshaft is 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 force valve to open by pressing on the same.

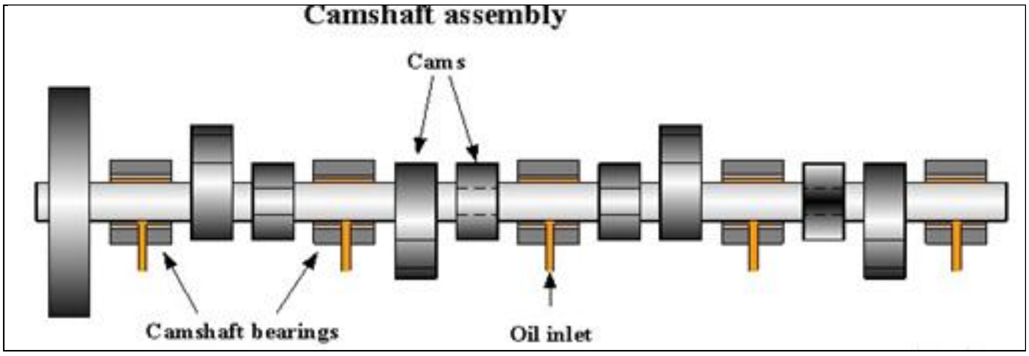

Fig 2: Camshaft

1.2 Follower:

The follower is used to transferring rotary motion to rocker arm mechanism which converts into leverage motion.

Types of follower:

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

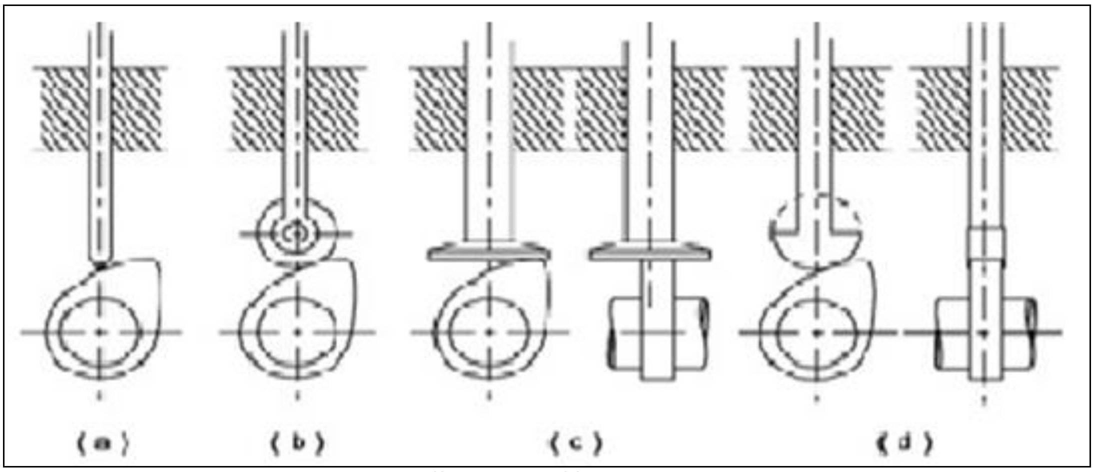

Fig 3: Different types of follower

1.3 Design of Ball Point Type Follower with Single Ball Groove Type Cam:

Different types of followers are used in an automobile. But in every cam and follower, friction and heat generation occurs.

Due to this friction and heat generation, follower life decreases. A cutting effect on the surface of the cam is also the result of friction. Because of these reasons arrangement and a successive pair of cam and follower get affected. Successive Pair of cam and follower remains incomplete.

In every mechanical component, there is no such system that lubrication would be provided at each place because of this there is a decrease in follower's life.

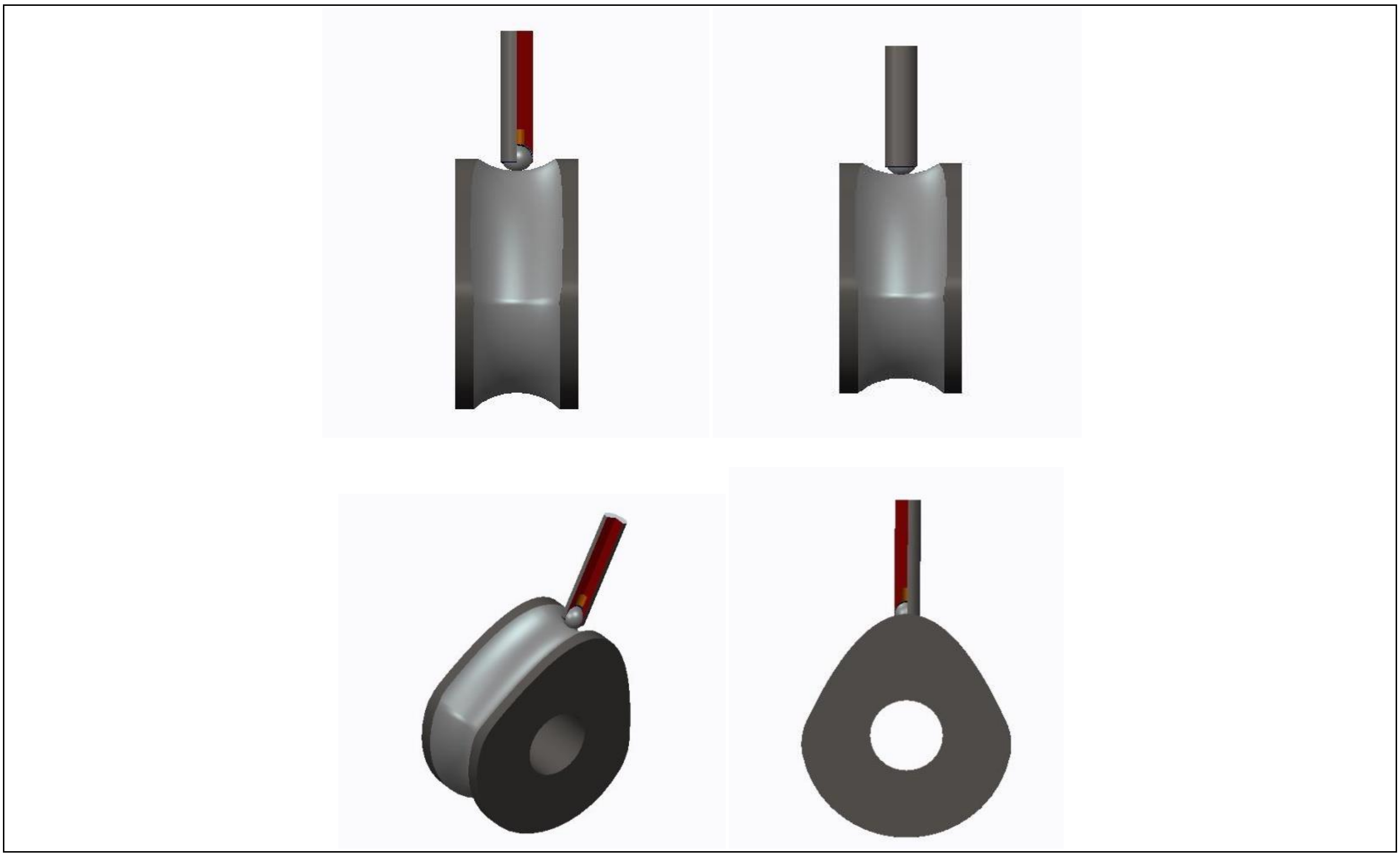

Fig 4: Design of Ball Point Type Follower with Single Ball Groove Type Cam

1.4 Single groove cam

In this type of design of cam, instead of the flat surface of cam, it is replaced by the undercut. Due to this Follower will work smoothly. As shown in the design.

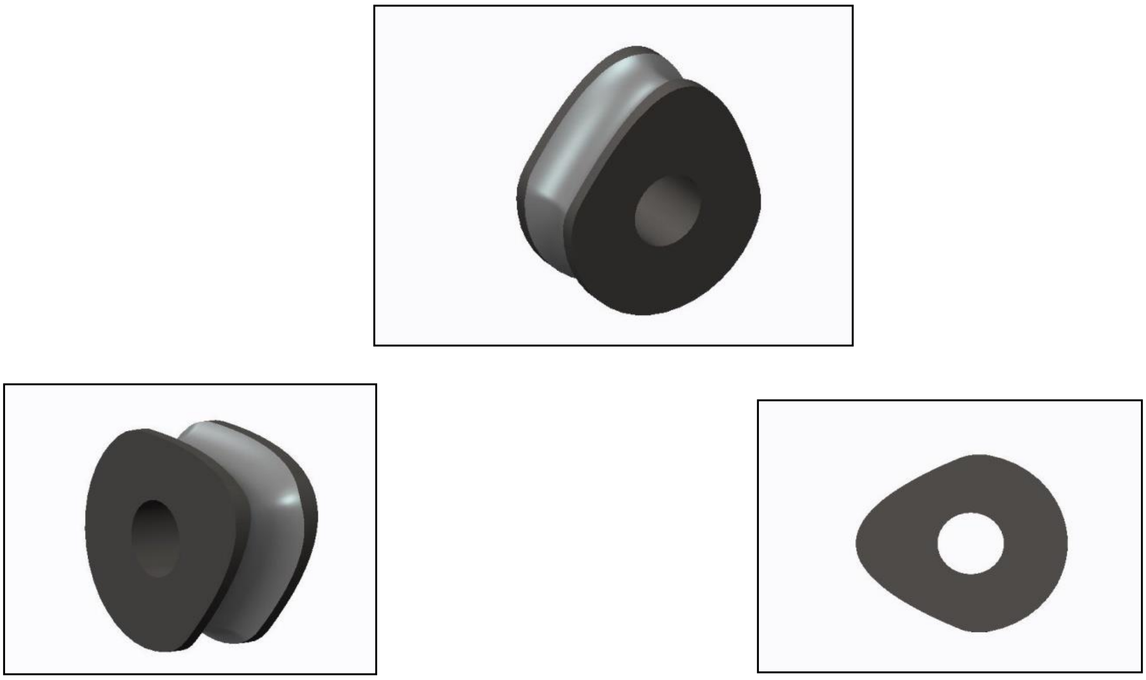

Fig 5: Single Groove Type Cam

1.5 Ball point follower

Ball point type follower design is inspired by the point of a ball pen.

This design works on the principle or mechanism of a ball pen. As in a design of ball pen rolling of ball happens and ink comes outside, it happens same in a case of ball point type follower. Inside a follower lubrication ball rolls and cam's groove comes in contact with that ball point. Lubrication is provided.

Heat generation is less between cams and followed. The decrease in friction. And considering all these parameters, single groove cam and ball point follower is designed. As shown in Fig.

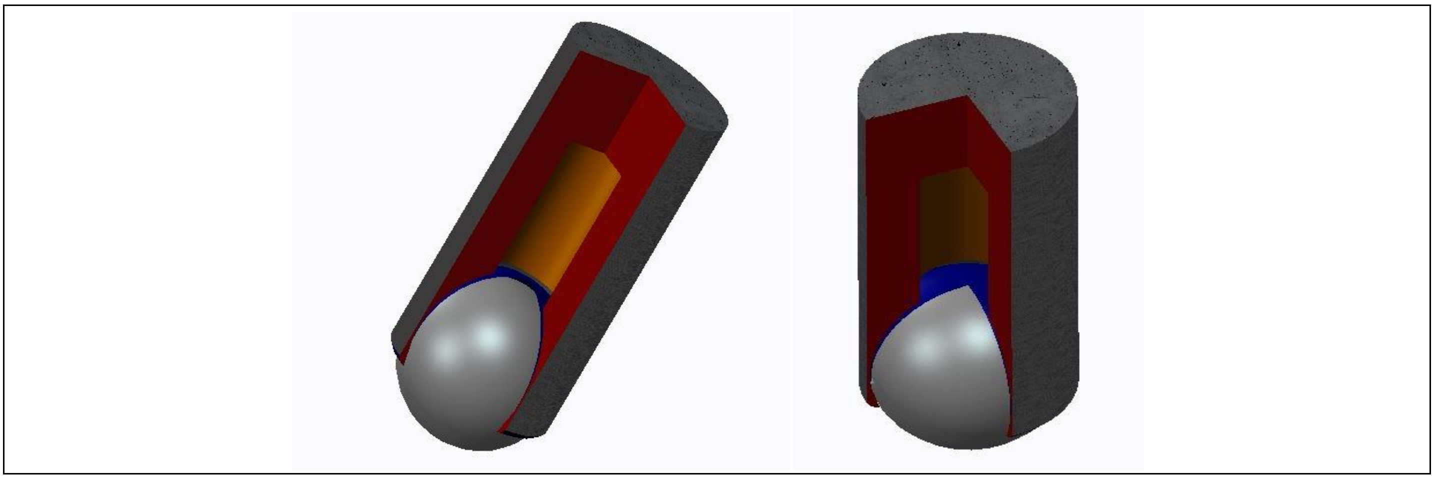

Fig 6: Ball Pen type Follower with lubricating oil groove

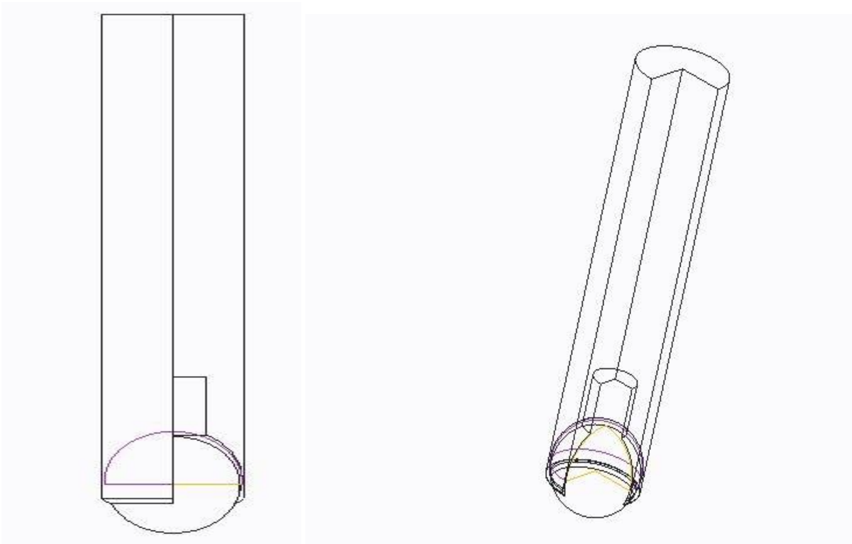

Fig 6: Cut Section of Ball Pen type Follower with lubricating oil groove

In this manner ball point, type follower will rotate on cam.

2. Calculations for Single Groove Cam and Ball Point Type Follower Design:
Calculate follower spring stiffness,
h= 00.0254m
β = 100°
N = 900 rpm

Spring constant $'k' = \frac{F}{x}$; where, x = spring displacement = 0.040 m …eq(1)

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

Max. Power @ 900 rpm = $\frac{900 \times 25.9}{5000}$ = 4.662 kW =4662 Nm/s

Linear velocity = v = $r \times RPM \times 0.10472$ …eq(2)

$= 64 \times 900 \times 0.10472$

v = 6.031872 m/s

$F = \frac{P}{v} = \frac{4662}{6.031872}$ = 772.9 N ≅ 773 N …eq(3)

Spring constant = $k = \frac{F}{x} = \frac{773}{0.040}$ = 19345.95 N/m …eq(4)

Cam Specification
W= 0.90 kg = 8.896 N
R_{max} = 0.020 m
R_{min}= 0.0175m
w= 0.016m
μ = 0.05

Follower Specification
d= 0.008m
d_f = 0.012m
d_l= 0.004m
$L_{1=}$ 0.080m

L_2= 0.030m

Where; W= weight acting on follower
R_{max}= max. Radius of cam circle
R_{min}= min. radius of cam circle
w= width of cam
μ= friction coefficient
d= dia. Of ball
df=dia of follower
d_l= dia of lubricant cylinder
L_1= length of follower
L_2= length of lubricant cylinder

Assuming rotation of cam is 75°
Equations of cycloid motion are:

Displacement = $y = h\left[\frac{t}{T} - \frac{1}{2\pi}\sin\left(2\pi\frac{t}{T}\right)\right]$ …eq(5)

Velocity = $v = y' = \frac{h}{T}\left[1 - \cos\left(2\pi\frac{t}{T}\right)\right]$ …eq(6)

Acceleration = $a = y'' = \frac{2\pi h}{T^2}\sin\left(2\pi\frac{t}{T}\right)$ …eq(7)

Where T= $\frac{60}{N}\cdot\frac{P}{360} = \frac{60}{900}\cdot\frac{100}{360} = {}^{1}\!/_{54}\,\text{sec.}$ …eq(8)

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) …eq (9)

$F_s = k(0.009 + y)$ …eq (10)
$= 19345.95(0.009 + 0.023)$
$F_s = 619.007N$ (Downward)

$$P = F_s - \frac{W}{g} y'' \qquad \text{...eq(11)}$$

$$= 619.007 - 421.51$$

P = 197.56 N

Normal force acting on follower,

$$F_n = \frac{P}{\cos\alpha - \left(2\mu \frac{l_1}{l_2} + \mu - \frac{\mu^2 d}{l_2}\right)\sin\alpha} \qquad \text{...eq(12)}$$

$$F_n = \frac{197.56}{\cos 10 - \left(2(0.05)\frac{0.080}{0.030} + 0.05 - \frac{0.05^2(0.004)}{0.030}\right)\sin 10}$$

$F_n = 210.456$ N

The torque acting on a cam from a radial translating Ball point follower,

$$T_0 = F_n \frac{y'}{W} \cos\alpha \qquad \text{...eq(13)}$$

INPUT PARAMETERS				
Parameter	Symbol	Object-1	Object-2	Unit
Object shape		Cylinder	Plane	
Poisson's ratio	ν_1, ν_2	.211	.26	
Elastic modulus	E_1, E_2	130	210	GPa
Diameter of object	d_1, d_2	24		mm
Force	F	202.75		N
Line contact length	l	7		mm
Calculate				

RESULTS				
Parameter	Symbol	Object-1	Object-2	Unit
Maximum Hertzian contact pressure	p_{max}	255.3		MPa
Max shear stress	τ_{max}	81.7	76.7	
Depth of max shear stress	z	0.018	0.057	mm
Rectangular contact area width	2b	0.144		

$$T_0 = 210.459 \times \frac{1.3716(60)}{900(2\pi)} \cos 10$$

$T_0 = 3.015$ Nm

Friction force,

$$F_f = \mu_r \times F_n \qquad \text{...eq(14)}$$

$$F_f = 0.05 \times 210.459$$

$$F_f = 10.522 \text{ N}$$

Linear wear being a linear decrement of the specimen:

$$\frac{Z}{l} = a_0\left(\frac{P_0}{H_1}\right)^{a_1}\left(\frac{H_2}{H_1}\right)^{a_2}\mu^{a_1} \quad \text{...eq(15)}$$

TABLE 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	-

$$\frac{Z}{0.08} = 1.13 \cdot 10^{-5}\left(\frac{255.3 \cdot 10^6}{450}\right)^{1.00}\left(\frac{370}{450}\right)^{2.69} 0.05^{3.23}$$

Z = 19.008 µm

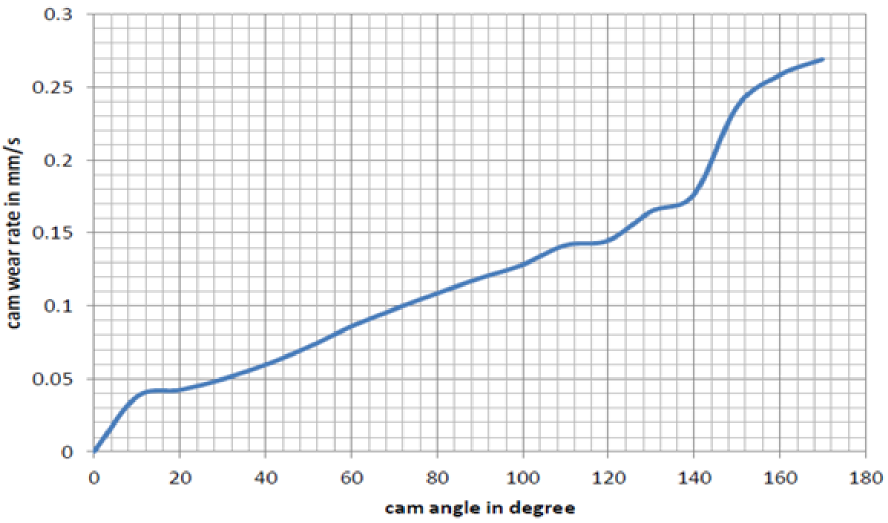

CHART 1: WEARING AT CAMSHAFT

3. CONCLUSIONS

We conclude that on this design of single groove cam and ball pen type follower the contact between the cam and follower is friction and heat generation is less than the other cam and follower and this is a new concept for mechanical and automobile industries. When both components are on moving and rotating motion the lubrication is must require for the follower. There are different types of followers like a knife edge, roller, flat type followers, but in all these types more friction and wearing takes place. So in concern to this friction and wearing issue, Single groove cam with ball point type follower design is presented. In this design of follower lubrication of follower will be there continuously and due to that heat generation, friction, wearing will be lesser comparatively from other followers.

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