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Design optimization of cam and roller follower for improving efficiency of an I.C engine

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***Abstract**: The existing cams used in internal combustion engines are made in a variety of forms which have a line contact with follower. As line contact between current cam and follower mechanism results in high frictional losses which results in low mechanical efficiency. Hence in this work an attempt is made to change the flat face of follower by using optimization technique, so that the required length of contact is reduced near about to point contact can be achieved to minimize frictional losses and the efficiency of the cam and roller follower will be improve.*
***Keywords:** Follower & Cam, Cylinder Contact surface, Line contact, Contact stresses.*

I. Introduction

A cam is a rotating machine element which gives reciprocating or oscillating motion to another element known as follower. The cams are usually rotated uniform speed by a shaft, but the follower motion is pre-determined and will be according to the shape of cam. The cam and follower is one of the simplest as well as one of the most important mechanisms found in mode machinery today. Cam and follower mechanism is preferred over a wide variety of internal combustion engines because due to the cam and follower it is possible to obtain an unlimited variety of motions.Most of the IC engines used in the market have roller cam and follower mechanisms, having a line contact between the cam and the roller follower. In an effort to improve the mechanical efficiency of the mechanism to change the design of roller follower by changing its parameters by varying the length and the radius that would be change in length of contact to reducing the friction with cam. Hence it is required to change the flat roller follower to a curved profile.

There are different types of follower are available in that the most commonly used follower in the internal combustion engine is flat face follower. When the contacting end of the follower is perfectly flat face then it is called as flat face follower. It may be noted that the side thrust between the follower and the guide is much reduced in case of flat faced followers. The only side thrust is due to friction between the contact surfaces of the follower and the cam. The relative motion between these surfaces is largely of sliding nature but wear may be reduced by off-setting the axis of the follower so that when the cams rotate, the follower also rotate about its own axis. The flat faced followers are generally used where space is limited such as in cams which operate the valves of automobile engine.

Material Used For Cam and Follower

The most commonly used material for the cam and follower is chromium steel with designation of 100cr6.Chemical composition and the mechanical properties of the material 100cr6 is given in the table below:

Chemical

C	Mn	Si	Cr	P	S	Ni	Mo	Other
0.95-1.10	0.20-0.40	0.15-0.35	1.35-1.65	0.030	0.030	0.40	0.10-	-

Composition:

Mechanical Properties:

Density(*1000kg/mm^3)	7.7-8.03
Poisson's Ratio	0.27-0.30
Elastic Modulus (Gpa)	190-210
Tensile strength (Mpa)	1158
Yield strength (Mpa)	1034
Elongation (%)	15
Reduction in Area (%)	53
Hardness (HB)	335

II. Literature Survey

[1] Prof. H.D.Desai Prof. V.K.Patel, in “Computer Aided Kinematic and Dynamic Analysis of Cam and Follower”, he said analysis becomes more complex when the engine does not have an overhead cam shaft, or when there is an overhead cam shaft that operates the valves by rockers. When this is the case the inertia of the rocker needs to be considered and the ‘lever effect’ of the rocker needs to be considered – as the two side arms of the rocker are frequently unequal. The analysis will depend upon the type of follower and the detailed geometry. Because of these difficulties with the analysis it was common for accelerations to be determined graphically.

[2] Khin Maung Chin , in ”Design and Kinematics Analysis of Cam-Follower System”, he said high accelerations are needed to give rapid opening and closing, too rapid a change in acceleration – the ‘jerk’ or ‘jerk rate’ – will give rough operation due to the sudden changes in forces. For this reason cam profiles are designed not to give very rapid changes in accelerations. It may also be noted that as higher forces can more easily be provided by the cam than by the valve springs, it is common to us higher accelerations when starting the opening of the valves and when slowing their closing at the end of the closing phase. These aspects are controlled by the cam, whereas the slowing of the valve at the end of the opening phase and the acceleration of the valve at the start of the closing phase are controlled by the valve springs.

[3] Teodorescu presented an analysis of a line of valve trains in a four-cylinder, four-stroke in-line diesel engine in order to predict the vibration signature taking into ac-count frictional and contact forces.

[4] Khin Maung Chin & Dr. David J Grieve, in” Design and Kinematics Analysis of Cam-Follower System”, “Forces in the Valve Train of an Internal Combustion Engine”, they will make some simplifying assumptions that a knife edge follower is being used. This will not be very accurate, but will give some idea of values. The simplest assumption for analysis is to assume that the opening and closing is simple harmonic motion (SHM).

[5] Cardona presented a methodology to design cams for motor engine valve trains using a con-strained optimization algorithm in order to maximize the time integral of the valve area opened to gas flow. He observed that profile errors can have a large influence on the dynamic performance of such high-speed follower cam systems.

[6] Jeon stated that with experimental and simulation results that optimizing a cam profile can in-crease the valve lift area while reducing the cam acceleration and the peak pushrod force. It can also avoid the jump phenomenon of the follower observed at certain.

III. Specification Of Problem Statement And Objective

The existing cam & follower mechanisms used in internal engine have a line contact between them causing high surface stress and frictional losses. These frictional losses in present line contact are being considered on the higher side. These frictional losses affect the total efficiency of an Internal Combustion engine. The degree of freedom required for variable valve timing (VVT) mechanism which can be able to achieve by design optimization of follower.

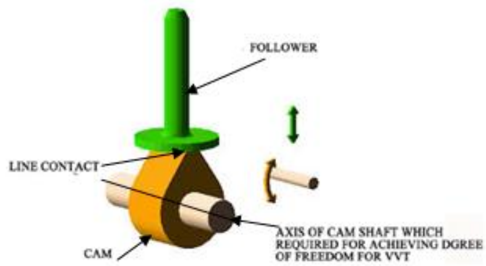


Figure 1. Existing cam & follower mechanism.

In order minimise these stresses and to reduce the friction losses the flat end of the follower is optimised by reducing the length of contact so that it will help in the increasing of the mechanical efficiency.

IV. Contact Stress Analysis

The problem of mechanical contact is that it is impossible to obtain an analytical solution for that. Real cylinders are of finite length and, although the contact stresses over the majority of the length of the cylinder are predicted accurately by the Hertz’s theory, significant deviations occur close to the ends.

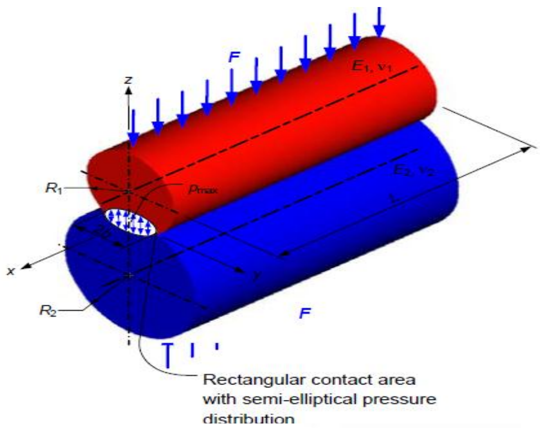
Characteristics of Contact Stresses

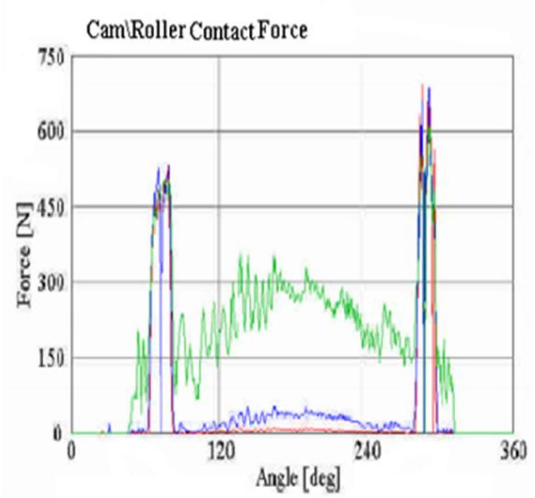
1. Represent compressive stresses developed from surface pressures between two curved bodies pressed together;
2. Possess an area of contact. The initial point contact (spheres) or line contact (cylinders) become area contacts, as a result of the force pressing the bodies against each other;
3. Constitute the principal stresses of a tri-axial (three dimensional) state of stress;
4. Cause the development of a critical section below the surface of the body;
5. Failure typically results in flaking or pitting on the bodies' surfaces.

Two design cases will be considered in the contact stress analysis
1. Sphere – Sphere Contact (point contact)
2. Cylinder – Cylinder Contact (line contact)
In most of the internal combustion engine flat face follower is used .There will be line contact between the cam and the flat face follower. So for this case Cylinder – Cylinder contact is considered.

V. Cylinders In Contact

Considering that cam and roller follower are held in cylindrical contact by forces *F* uniformly distributed along the cylinder length *l*.





Where,
E_1, E_2 =Elastic moduli for cylinder 1and 2
μ_1, μ_2 = Poisson's ratio for cylinder 1 and 2.
F= Applied force
L = Length of cylinders 1 and 2 (L_1=L_2 assumed)
R1, R2= Radius of Roller follower and cam respectively.

By referring above graph the force value is taken as 650. The resulting pressure causes the line of contact to become a rectangular contact zone of half width *b* given as:

$$b = \sqrt{\frac{4F[\frac{1-\mu_1^{2}}{E_1} + \frac{1-\mu_2^{2}}{E_2}]}{\pi L(\frac{1}{R_1} + \frac{1}{R_2})}}$$

The maximum contact pressure between the cylinders acts along a longitudinal line at the center of the rectangular contact area, and is computed as,

$$P_{\max} = \frac{2F}{\pi bL}$$

The equation for the radius of the contact area, maximum contact pressure, and principal stresses along the x axis are

$$a = 2\sqrt{\frac{P}{\pi L}\frac{R_1R_2[(1-\mu_1^{2})\mathrm{E}_1 + (1-\mu_2^{2})E_2}{E_1E_2(R_1+R_2)}}$$

Cylinders in Contact – Principal Stresses

The principal stresses σ1, σ2, and σ3 are generated on the z-axis:

$$\sigma_x = \frac{-P_{\max}}{\sqrt{1+\tau^2}}$$

$$\sigma_y = -P_{\max}(\frac{1+2\tau^2}{\sqrt{1+\tau^2}} - 2\tau)$$

$$\sigma_z = -2\mu P_{\max}\sqrt{1+\tau^2} - \tau$$

Where a and L are the half-width and length of the contact zone, respectively, and $\tau = \frac{x}{a}$

VI. Analytical Calculation

For doing optimisation of flat face follower for converting a line contact into a point contact the following Input parameters are considered

Input Parameter

Radius of roller, R_1 - 18mm
Base radius of cam, R_2 - 28mm
Modulus of elasticity of roller material, E_1 - 210000 N/mm^2
Modulus of elasticity of cam material, E_2 - 210000 N/mm^2
Force acting on cam, P - 650 N
Poisons ratio of roller material, μ_1 - 0.3
Poisons ratio of cam material μ_2 - 0.3

Output Parameter

$(1-\mu_2^2)$ E_1	191100
$(1-\mu_1^2)$ E_2	191100
$E_1.$ $E_2.(R_1+R_2)$	2.0286E+12

The parameters of roller follower like length of contact and the radius of follower is reduced by 0.5mm and for each parameter we calculated the values of contact area (a) in mm, Maximum contact Pressure (P_{max}) in N/mm^2, Maximum shear stress(τ_{max}) in N/mm^2 and also von mises stress (σ_{vm}) in N/mm^2.

L(mm)	R1(mm)	E1.E2(R1.R2)	P/(3.14*L)	a (mm^2)	P_{max}(N/mm^2)	τ_{max} (N/mm^2)	σ_{vm} (N/mm^2)
10.5	18	2.0286E+12	19.715	0.09	455.65	136.70	254.25
10	17.5	2.007E+12	20.701	0.09	470.95	141.28	262.79
9.5	17	1.9845E+12	21.790	0.09	487.54	146.26	272.05
9	16.5	1.96245E+12	23.001	0.09	505.60	151.68	282.12
8.5	16	1.9404E+12	24.354	0.09	525.34	157.60	293.14
8	15.5	1.91835E+12	25.876	0.09	547.04	164.11	305.25
7.5	15	1.8963E+12	27.601	0.10	571.01	171.30	318.62
7	14.5	1.87425E+12	29.572	0.10	597.65	179.30	333.49
6.5	14	1.8522E+12	31.847	0.10	627.47	188.24	350.13
6	13.5	1.830155E+12	34.501	0.10	661.10	198.33	368.89
5.5	13	1.8081E+12	37.638	0.11	699.40	209.82	390.27

Check:

These values of τ_{max}, σ_{vm} .Are compared with the allowable stress value. The calculated stress is comparatively less than the allowable stresses so the design is under safe conditions with considering the factor of safety.

Yield strength	1034 N/mm2	
Tensile strength	1158 N/mm2	
FOS		1.5
Allowable stress	772.0 N/mm2	

As all the values of τ_{max} & σ_{vm} are below the allowable stress value so the design is safe.

VII. Conclusion

As we are going to optimize the design by modifying the geometry of a roller follower by varying its parameters like length of contact and the radius of the roller follower. By reducing the length of line of contact the stress values are goes on increasing but these stress values are comparatively less than that of the allowable stress values so the design of a modified roller follower is safe.This indicates that change of the flat face of roller follower by reducing the line of contact with respective cam mechanism results in low frictional losses due less contact area which results in improved the mechanical efficiency of a cam and roller follower mechanism.

References

[1]. Prof. H.D.Desai Prof. V.K.Patel, "Computer Aided Kinematic and Dyamic Analysis of Cam and Follower", Proceedings of the World Congress on Engineering 2010 Vol II WCE 2010, June 30 - July 2, 2010, London, U.K.

[2]. Khin Maung Chin, "Design and Kinematics Analysis of Cam-Follower System", GMSARN International Conference on Sustainable Development: Issues and Prospects for the GMS 12-14 Nov. 2008

[3]. M. Teodorescu, M. Kushwaha, H. Rahnejat and D. Taraza, "Elastodynamic Transient Analysis of a Four-Cylinder Valve Train System with Camshaft Flexibility," Pro- ceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-Body Dynamics, Vol. 219, No. 1, 2005, pp. 13-25.

[4]. Dr. David J Grieve, "Forces in the Valve Train of an Internal Combustion Engine", 23rd February 2004.

[5]. A. Cardona, E. Lens and N. Nigro, "Optimal Design of Cams," Multibody System Dynamics, Vol. 7, No. 3, 2002, pp. 285-305.

[6]. H. S. Jeon, K. J. Park and Y.-S. Park, "An Optimal Cam Profile Design Considering Dynamic Characteristics of a Cam Valve System," Experimental Mechanics, Vol. 29, No. 4, 1989, pp. 357-363.